FINAL

ABANDONED MINE LANDS

BELT - SAND COULEE, MONTANA

WESTECH / HYDROMETRICS

VOLUME I

Volume I

Master Plan
Abandoned Mine Lands Reclamation
Sand Coulee and Belt Creek Areas

For:

Department of State Lands
Abandoned Mine Lands Program
Reclamation Division
Capitol Station
Helena, MT. 59620

By:

Hydrometrics
2727 Airport Road
Helena, MT. 59601

Western Technology and
Engineering, Inc.
3005 Airport Road
P.O. Box 6045
Helena, MT. 59604

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I. Introduction

A study of abandoned mine lands in the Belt/Sand Coulee area southeast of Great Falls was conducted through the Abandoned Mine Lands program of the Department of State Lands. Funded by taxes levied on coal, and mandated by federal legislation, the Abandoned Mine Lands program has targeted several areas of study throughout the state.

Impacts to water quality caused by acid mine drainage flowing from abandoned mines raised the question of effects to human health from these waters. Human health and safety are priority ranking elements utilized in determining which projects qualifying under the AML program warranted immediate study.

The investigation of the Belt/Sand Coulee area involved not only a determination of the hydrologic impact of discharging wells, but described the soil and vegetation, air quality and socioeconomic effects of the presence of abandoned mines. The studies were performed as a joint venture by two Helena consulting firms, Hydrometrics and Western Technology and Engineering, Inc. (WESTECH).

II. Purpose and scope

The purpose of the environmental resource investigation was to determine basal information regarding water quality/quantity, air quality, soils, and vegetation present at each site. Concurrent with the environmental investigations, a socioeconomic study was undertaken to determine the effect, if any, of abandoned mines on commercial and residential real estate values, and to describe, qualitatively, residents' point of view regarding their quality of life.

To achieve this purpose, a program of water quality and quantity monitoring was initiated, the aquatic biology of each drainage was investigated, air quality monitoring stations were established and a resident questionnaire distributed.

Current acid mine drainage and state-of-the-art reclamation procedures were determined by a comprehensive literature review. Results of the environmental investigations were combined with applicable reclamation procedures to develop site specific recommendations in a Master Plan for each drainage.

III. Master plan organization

The master plan for each drainage has been developed from the individual technical investigations conducted. These individual reports are appended to the master plans and contain the environmental analyses utilized to develop site specific recommendations.

Matrices have been formulated which present specific site components and abatement techniques. Where possible, reclamation procedure costs have been added as an element to each matrix.

The master plans include sources of air and water pollution, effects of pollution on aquatic systems, methods for acid drainage correction, surface and mineral ownership, recommendations for future monitoring and, through review of the matrices, projects for reclamation.

Slides or photos of each state designated site are contained in Exhibit A. These sites are mapped on U.S.G.S. base maps located in the Helena offices of the Abandoned Mine Lands Program, Department of State Lands.

Exhibit A. Photo record, state designated abandoned mine land sites, Sand Coulee/Belt areas.

GENERAL DESCRIPTION

IV. General Description

A. Geographic location

The Sand Coulee area is in central Montana and is located approximately 10 miles southeast of Great Falls, Montana. The general study area consists of about 118 square miles contained in Townships 18, 19 and 20, North and Ranges 4 and 5 East. Centerville, Stockett, Tracy, and Sand Coulee are located in the central portion of the study area along Sand Coulee Creek and its tributaries(Figure 1).

The community of Belt is approximately 17 miles east of Great Falls and is adjacent to Belt Creek. Belt Creek has a drainage area of approximately 524 square miles and is located in Townships 13-21 North, Ranges 5-9 East: the study area focuses on the towns of Belt and Armington, and extends to Belt Creek's confluence with the Missouri River (Figure 2).

B. Climate

The climate of the Sand Coulee and Belt areas influences streamflows, groundwater recharge, mine discharges and existing water quality. Potential control or abatement techniques would also be influenced by climate. No climatic data are available for the Sand Coulee and Belt areas; however, Great Falls is about 10 miles northwest of Sand Coulee and climatic data for Great Falls is used to characterize both the Sand Coulee and Belt study area. Climatological data for the Great Falls area are summarized in Table 1. This information includes 41 years of record.

The Great Falls area is classified as semiarid, with a total annual precipitation of about 15 inches per year. Seventy percent of the precipitation occurs during the months of April through September. Although an average of over 58 inches of snow falls each year in the Great Falls area, most precipitation occurs as rainfall.

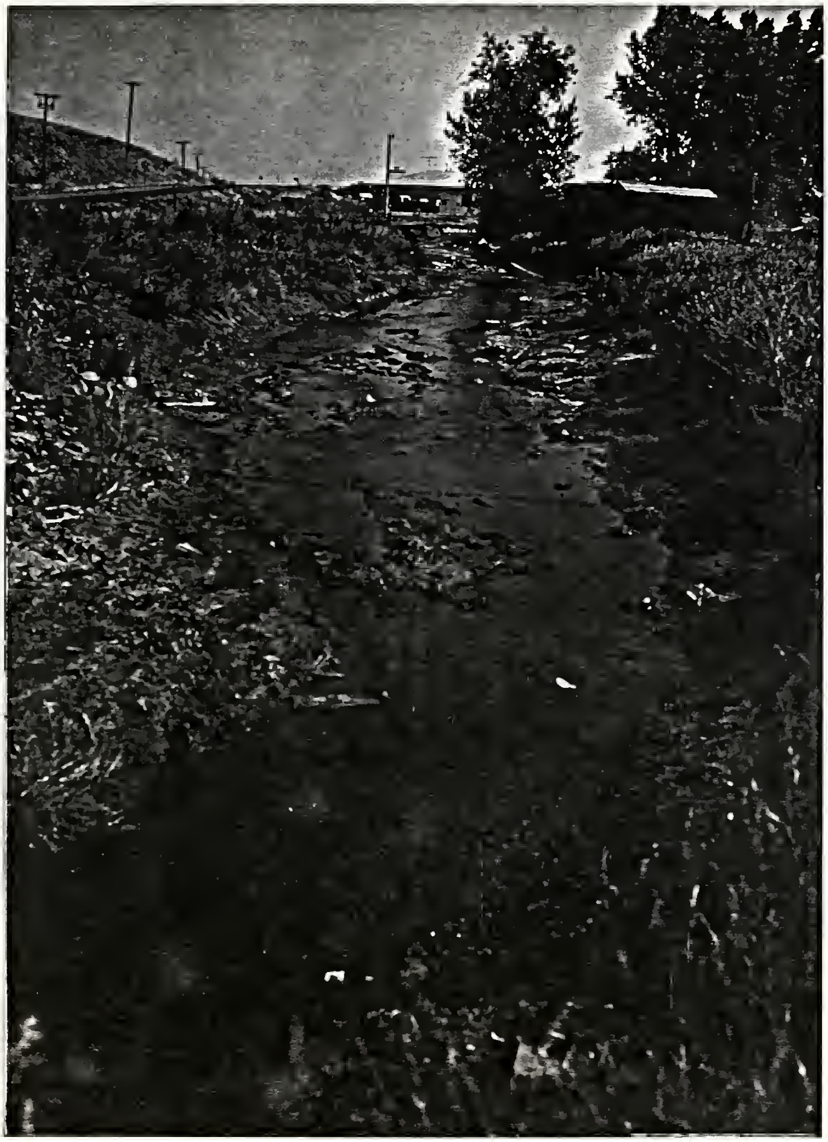

Fig. 1. Creek at Tracy showing the effects of discharging mine water.

Fig. 2. Mine spoils piles effecting Belt Creek and town of Belt.

TABLE 1. CLIMATOLOGICAL DATA FOR GREAT FALLS, MONTANA

	J	F	M	A	M	J	J	A	S	O	N	D	ANNUAL
Average Temperature (^{O}F)													
Mean	21.0	26.2	31.5	43.5	53.4	61.0	69.6	67.7	57.6	48.3	34.5	26.7	45.1
Maximum	30.2	36.0	41.6	54.6	65.0	72.7	83.7	81.6	70.0	59.3	43.6	35.4	56.1
Minimum	11.8	16.4	21.4	32.3	41.7	49.3	55.4	53.4	45.2	37.3	25.4	18.0	34.0
Precipitation	0.88	0.69	0.94	1.29	2.37	2.85	1.20	1.20	1.17	0.76	0.76	0.74	14.82
Snowfall	10.2	8.5	9.8	7.5	1.4	0.4	0.0	0.0	1.3	2.9	7.5	8.7	58.2
Wind													
Mean Speed (M.P.H.)	15.6	14.8	13.5	13.0	11.6	11.4	10.2	10.4	11.5	13.5	14.9	16.0	13.0
Prevailing Direction	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW	SW

Source: Information taken from National Weather Service, Local Climatological Data, Annual Summary with Comparative Data 1978, Great Falls, Montana.

The mean annual temperature in the Great Falls area is 45^{O}F. The average high temperatures is 56^{O}F and the average low temperature is 34^{O}F. High temperatures do reach 100^{O}F or more during late summer, and there are generally about 15 days each year when temperatures exceed 90^{O}F. Subzero temperatures are common throughout the winter months and often times temperatures drop below -25^{O}F. Extended periods where temperatures are below 0^{O}F are usually rare, however, due to the warm, dry chinook winds which are common in the area. Chinooks are strong, dry, warm winds which develop along the lee slope of mountain ranges.

The onset of a chinook is marked by a rise in temperature and a drop in humidity. The change is particularly abrupt in the winter when temperatures are often below zero. If snow is on the ground, the sudden increase in temperature causes the snow to melt quite rapidly. When snow cover is thick, the rapid thaw can cause flooding.

Temperature and rainfall have a significant effect upon hydrology and soil characteristics. The hythergraph is a climagram that relates temperature and rainfall (Figures 3-8).

By using weather data from the airport weather station at Great Falls, hythergraphs have been prepared for the years 1975, 1976, 1977, 1978, 1979, and 1980, to date. The data used are the average monthly temperatures (degrees Fahrenheit) and total monthly precipitation (inches). A balloon is plotted for each month at the appropriate temperature and precipitation. A string is drawn from the monthly mean to the balloon. Each balloon is numbered by calendar month. At a glance, the monthly temperature and precipitation and variation from the mean can be seen. Also, as the months proceed, the duration of spells can be assessed.

Table 2.

GREAT FALLS, MONTANA

AVERAGE MONTHLY TEMPERATURE (T), FAHR.

TOTAL MONTHLY PRECIPITATION (P), INCHES

		YEAR						
MON.	PARA.	1975	1976	1977	1978	1979	1980	MEAN
JAN	T	22.7	26.4	21.6	7.7	6.5	15.2	20.5
	P	1.14	0.57	1.04	1.68	0.71	0.67	0.88
FEB	T	13.1	30.5	39.2	14.5	18.8	28.1	26.6
	P	0.71	0.53	0.19	1.21	0.57	1.03	0.75
MAR	T	27.4	31.6	34.0	33.6	34.7	32.4	30.5
	P	1.34	0.75	1.90	0.41	1.00	0.74	0.97
APR	T	30.9	46.1	47.1	44.1	40.7	52.9	43.4
	P	4.63	2.33	0.26	1.76	2.05	0.62	1.18
MAY	T	50.0	56.9	51.3	51.3	51.5	57.1	53.3
	P	3.89	0.88	2.11	3.20	0.69	5.12	2.37
JUN	T	58.8	61.0	65.4	62.5	62.9	60.9	60.8
	P	4.47	4.10	0.54	2.56	2.61	3.91	3.11
JUL	T	71.8	70.3	68.0	67.1	69.0	69.4	69.3
	P	1.20	2.07	1.87	1.99	0.27	0.27	1.27
AUG	T	64.8	67.9	62.5	66.5	68.5		67.4
	P	2.13	1.91	1.94	1.04	0.29		1.09
SEP	T	57.3	61.2	56.1	58.8	62.9		57.3
	P	0.74	0.61	2.22	2.56	0.33		1.17
OCT	T	45.7	46.5	47.8	48.8	49.4		48.3
	P	3.43	0.19	0.51	0.27	0.84		0.68
NOV	T	32.9	36.6	30.8	23.9	33.4		34.6
	P	1.01	0.65	0.43	1.44	0.29		0.81
DEC	T	28.6	31.6	16.5	17.4	34.6		26.5
	P	0.55	0.51	1.92	1.05	0.26		0.71

Ref. Climatological Data, Montana, National Climatic Center, Asheville N.C.

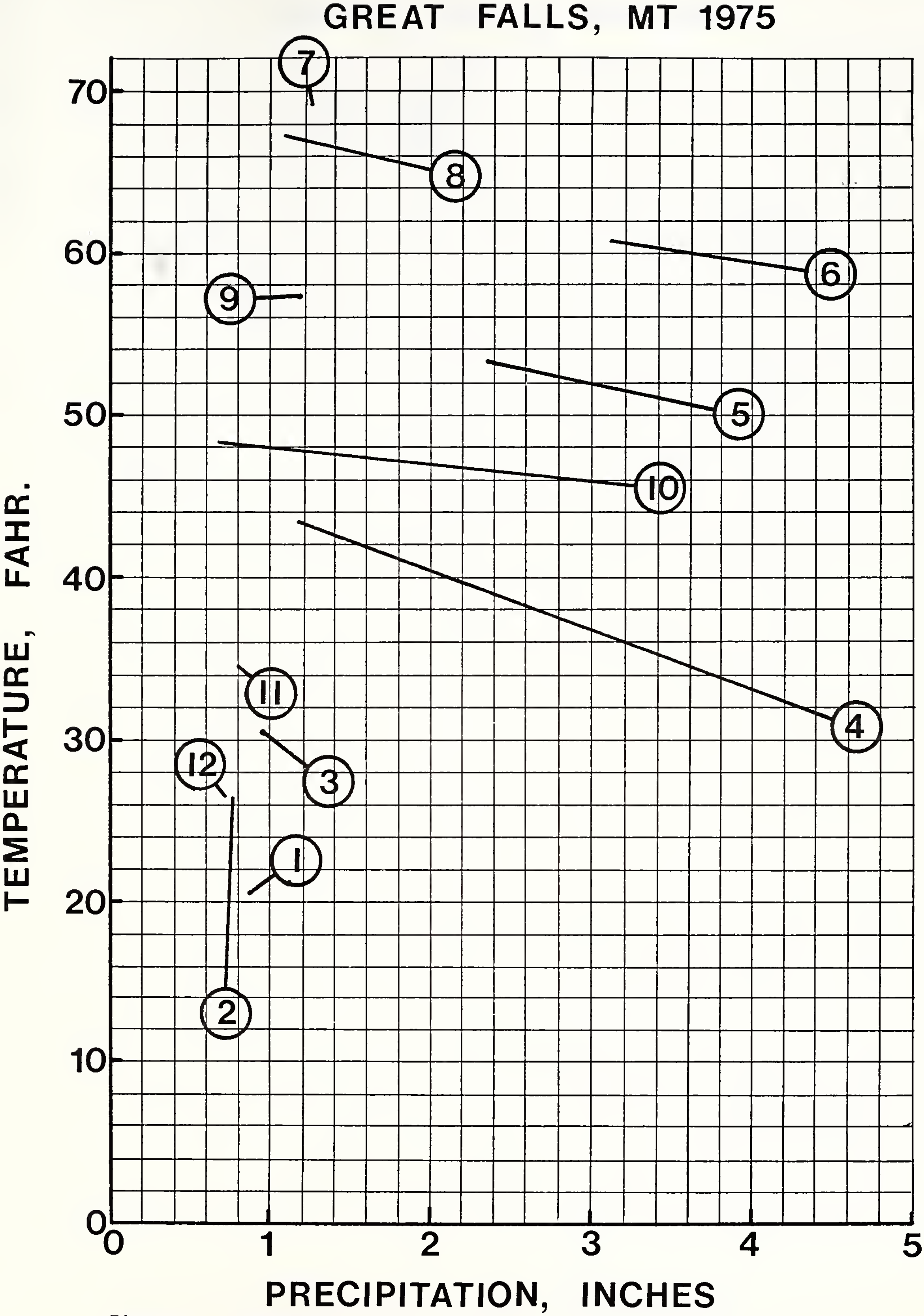

Figure 3. Temperature and precipitation, Great Falls, 1975.

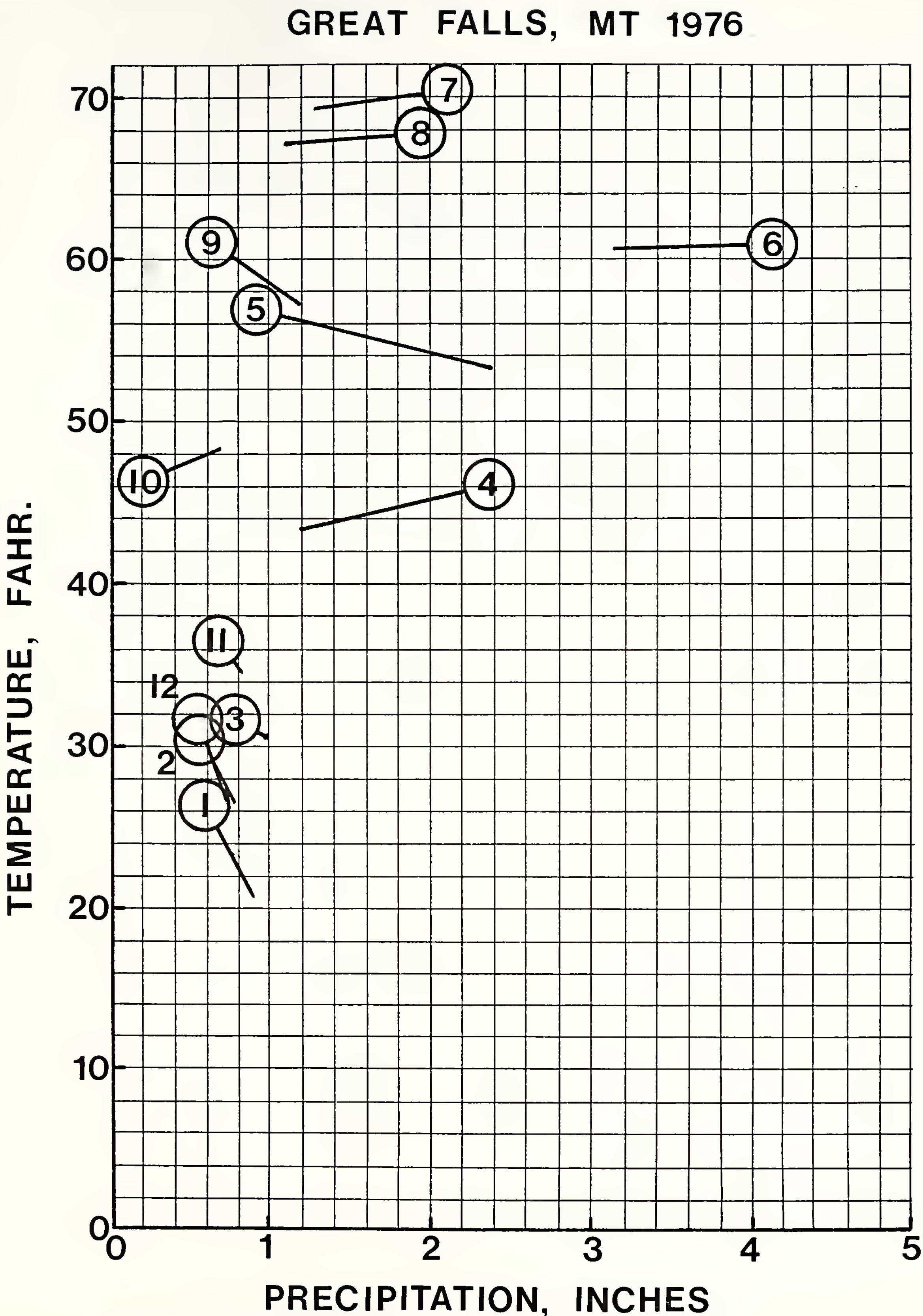

Figure 4. Temperature and precipitation, Great Falls, 1976.

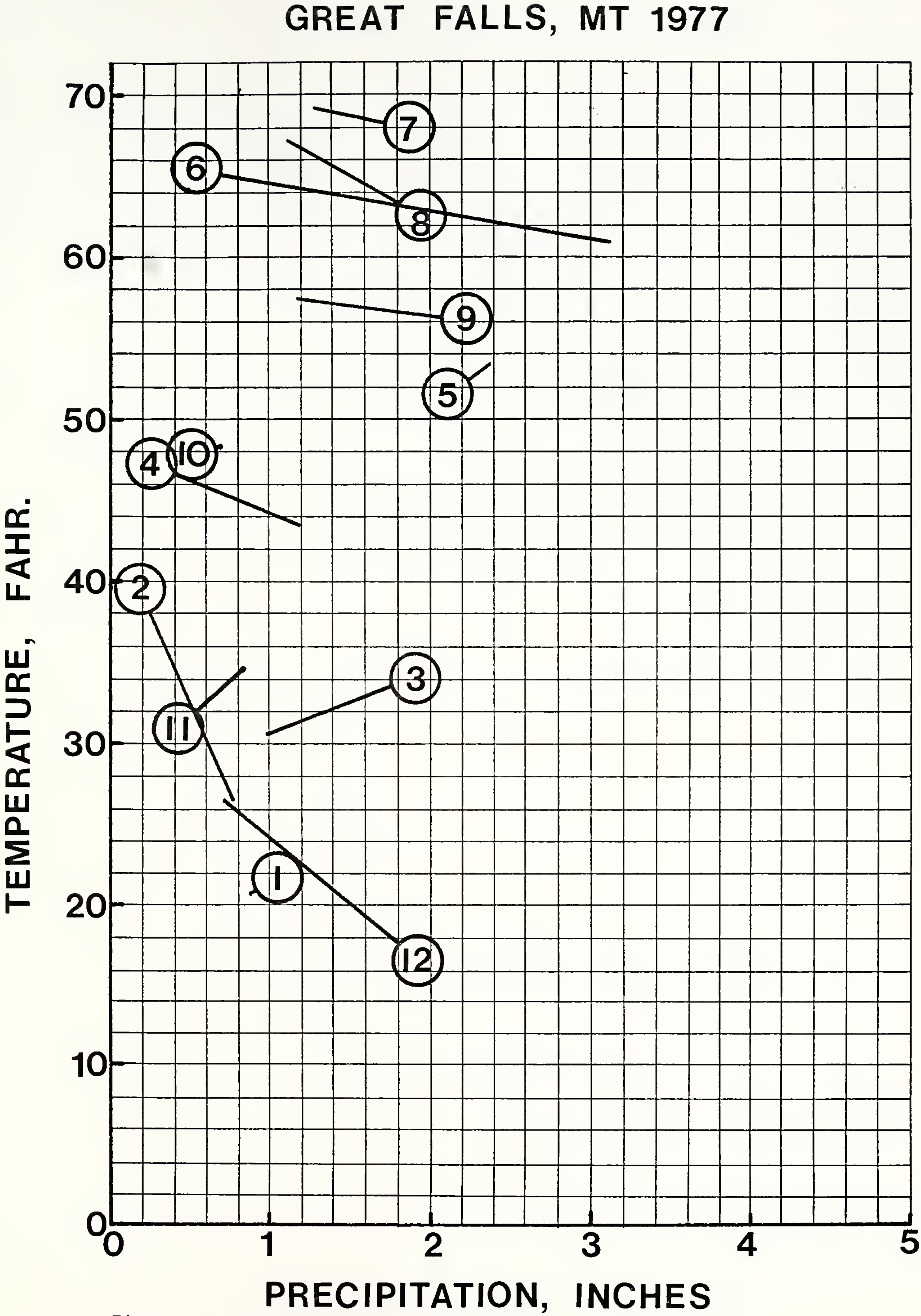

Figure 5 Temperature and precipitation, Great Falls, 1977.

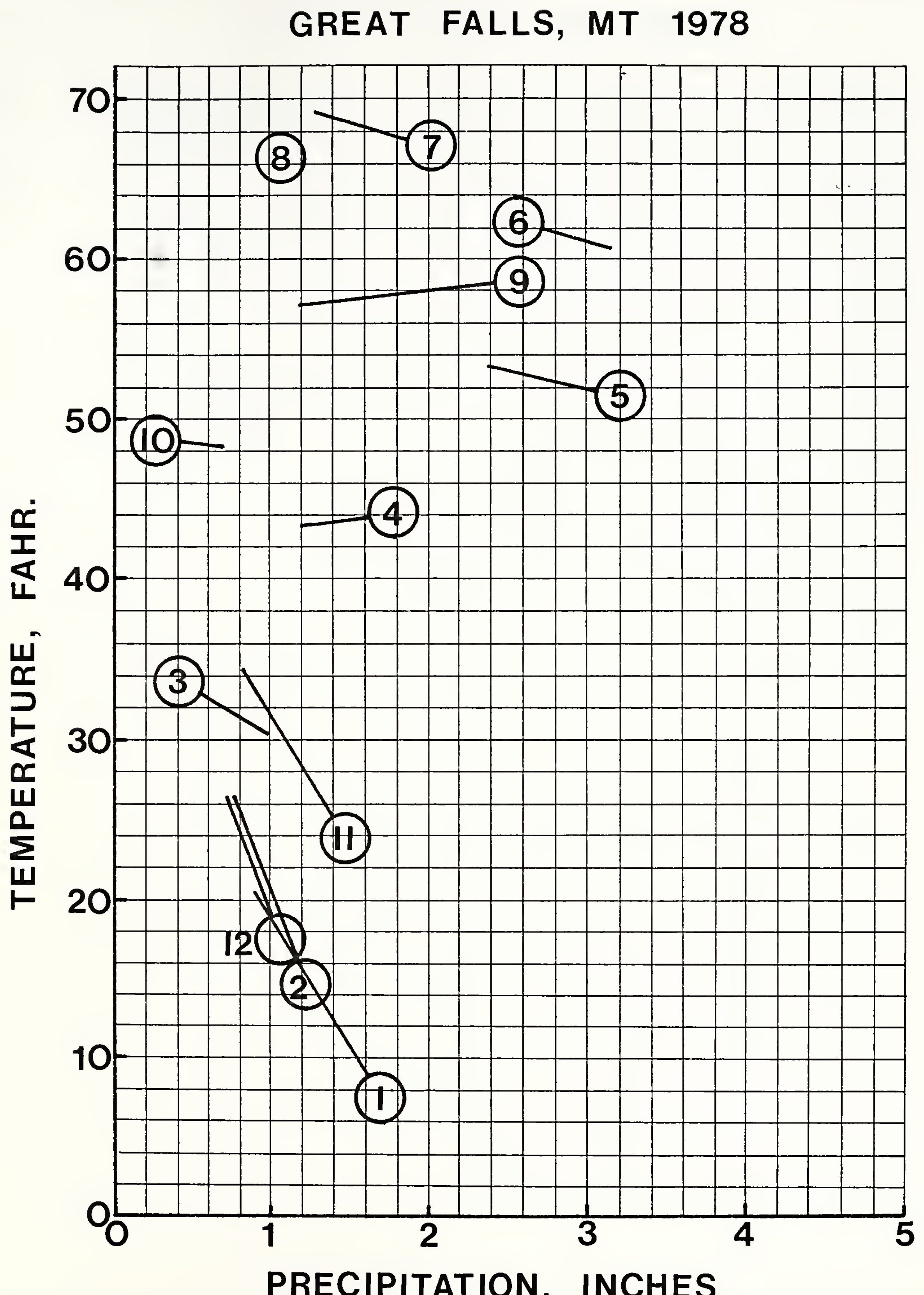

Figure 6. Temperature and precipitation, Great Falls, 1978.

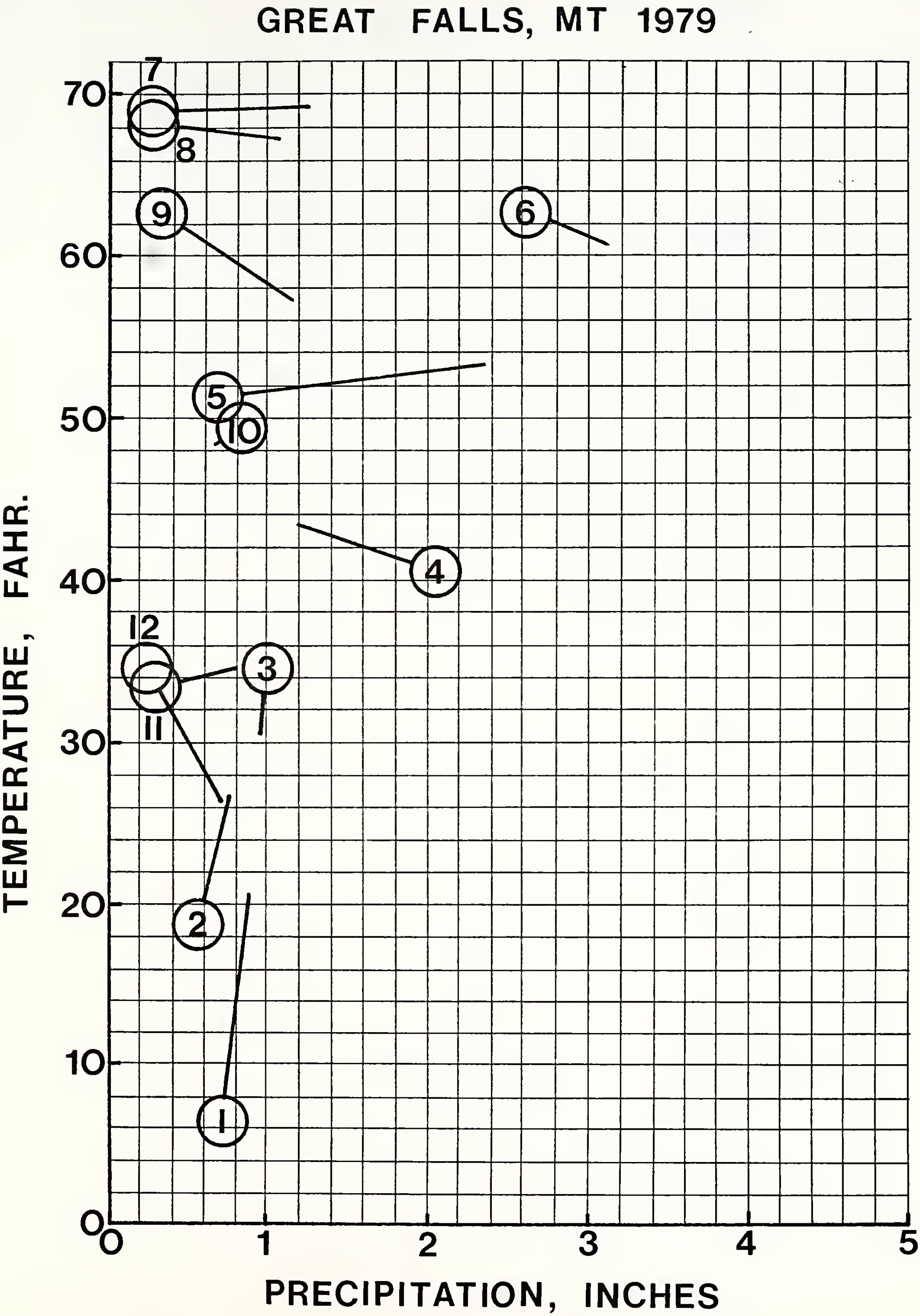

Figure 7. Temperature and precipitation, Great Falls, 1979.

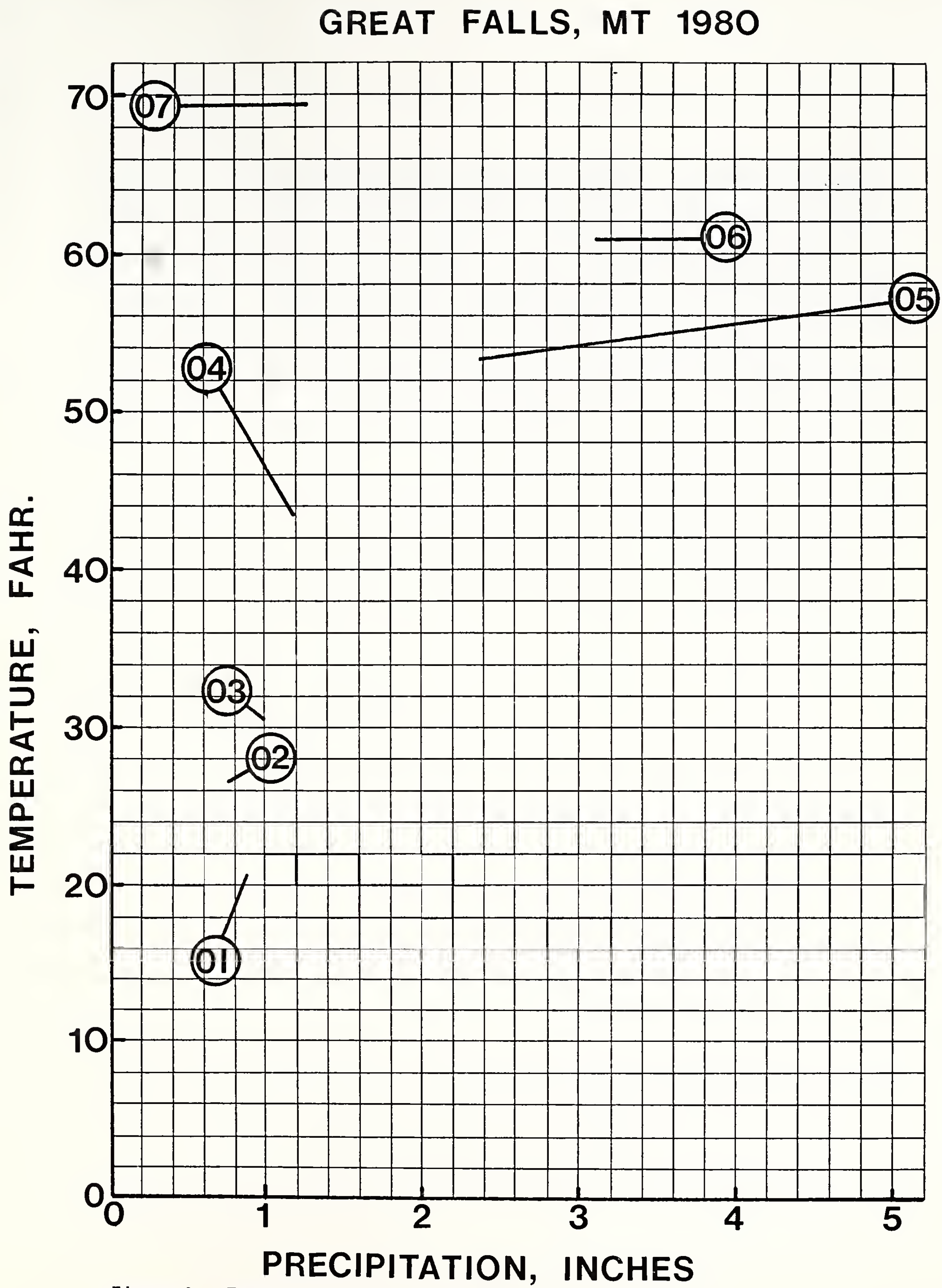

Figure 8. Temperature and precipitation, Great Falls, 1980.

C. Land use

1. Sand Coulee

Land uses in the Sand Coulee area include residential, cropland and unimproved range. Several hundred homes are located within the study area and are mainly concentrated in the towns of Tracy, Sand Coulee, Centerville, and Stockett. These towns are all located in the Sand Coulee Creek drainage and are within a four mile radius. All four towns are essentially mining towns which were developed in the late 1800's and early 1900's to house miners working in the nearby coal mines.

Most of the land located beyond the four towns is used for agricultural purposes. Land on the benches above the coulees is used primarily as rangeland for livestock and in some areas as cropland. The more fertile bottomlands along the creeks and coulees are used as farmland to produce barley, oats, wheat, and hay. Farming is basically dryland and both continuous cropping and summer fallow practices are utilized.

There is no current mining of coal or other minerals in the area, although it is reported that some local residents still remove small quantities of coal for their personal use. A few sites along Sand Coulee Creek near the north end of the study area are used for local gravel supplies. One area south of Sand Coulee was used as a sanitary landfill, however, it did not meet state landfill standards and was recently closed.

2. Belt

The Belt Creek valley contains several hundred homes distributed between the towns of Belt and Armington. Both towns were developed as a result of intensive coal mining activity in the late 1800's. The Burlington Northern Railroad has operated a minor switchyard facility in Belt since

the early 1900's and this also has made a contribution toward the economic base of the area.

Agriculture is the dominant land use in the valley. Much of the valley floor is subirrigated for grain crops, and falls in a 100 year flood plain designated by Cascade County. There has been some minor subdivision activity since 1970 downstream from Belt and in the vicinity of Armington. The areas surrounding the valley proper are mainly utilized for dryland farming and rangeland (Figure 9).

D. Mining history

1. Sand Coulee

Three large coal companies previously operated in the Sand Coulee area; the Cottonwood Coal Company, Nelson Coal Company, and the Gerber Coal Company. Several other smaller companies, including numerous individual operators, produced coal from the area, the most notable being the Mount Oregon Coal Company. Most of the coal mining activity started in the late 1880's and continued until the mid 1940's. The coal was principally used by railroads to operate steam locomotives, although some coal was used for home heating. Coal mining gradually declined in the 1940's with the advent of diesel locomotives and increased availability of cheaper fuels such as natural gas and heating oils. In the early 1900's when coal mining was at its peak, the Sand Coulee mines were the largest producers of coal in Montana. It is estimated that coal mining production in the area probably exceeded 10,000 tons per day during the peak years. Production of coal, coal quality and mining information is described by McDermott (1906), Welsh (1905) and Fisher (1906 and 1909) (Figure 10).

All mining in the Sand Coulee area was essentially underground. In

Fig. 9. Example of mine waste impacting range lands.

Fig. 10. Rangeland impacts in the Giffen mine area.

general, one main adit (horizontal passageway) was driven into the face of a hillside and extended through the coal seam for several thousands of feet. Several large crosscuts were then driven laterally through the coal seam from the main adits leaving large support pillars between the openings.

Mining in this manner is referred to as the room and pillar technique. As the mines increased in size, new underground workings were constructed and more adits or passageways were added. In some of the larger mining operations, mine shafts (vertical passageways) were sunk from the ground surface to the adits to provide air for the underground miners and/or removal of coal and waste. In most instances coal wastes, i.e., the carbonaceous shales, low grade coal, or other waste rock excavated during mining, were transported to the entryway and discarded along the hillsides near the portal.

2. Belt

Earliest recorded coal mining in Cascade County was in 1876 near Belt, Montana and predates by three years the development of silver mining in the headwaters of Belt Creek. Coal production was substantial until the early nineteen-fifties when coal assumed a poor competitive position with respect to natural gas and oil and railroads made the changeover to diesel locomotives (Water Resources Survey for Cascade County, 1961). Some of the larger mines, including the Castner-Anaconda and Lochray-Anaconda mines, were located at Belt. The Castner-Anaconda mine was estimated to have produced about 300,000 tons per year for 25 years (7.5 million tons, total). The Lochray-Belt mine was estimated to have produced 230,000 tons per year for ten years (Silverman and Harris, 1967) (Figure 11).

Mining in the Belt area was essentially all underground by the room and pillar technique, described previously.

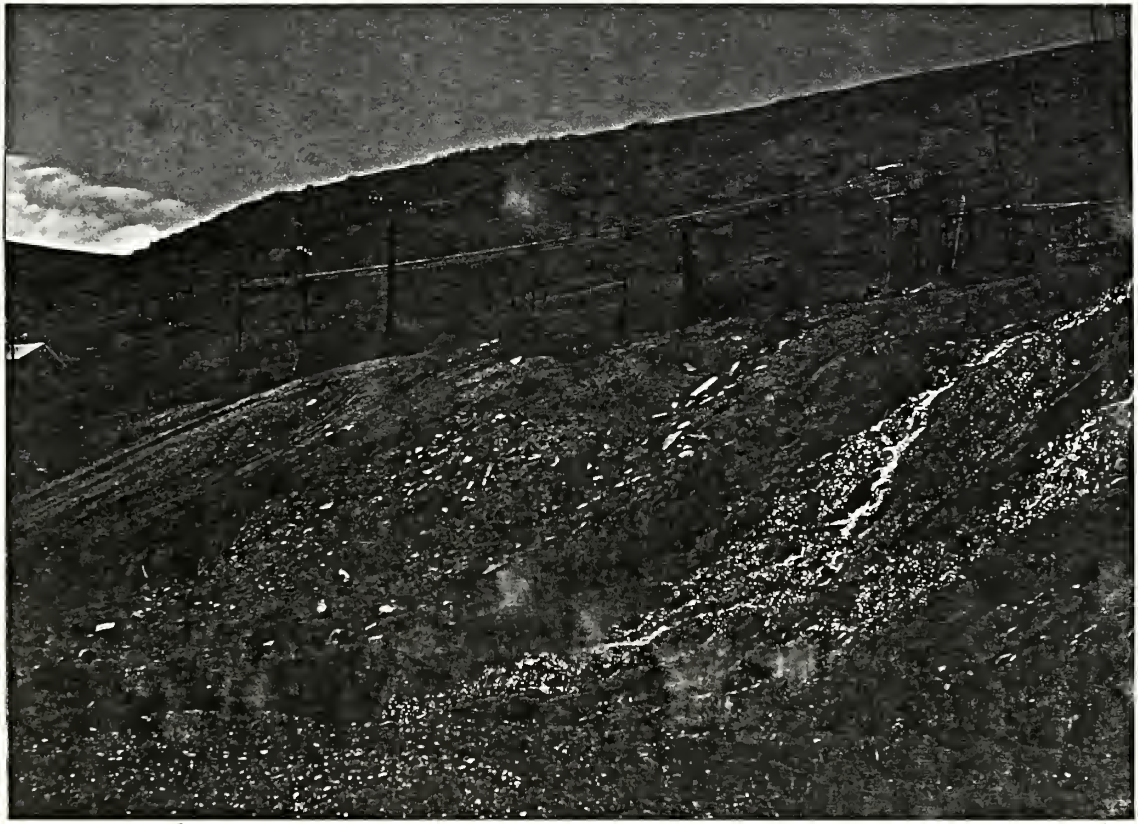

Fig. 11. Mine water discharging into Belt Creek west of town of Belt.

TECHNICAL SUMMARIES

V. Technical Summary

A. Hydrology

Many of the abandoned coal mines in the Sand Coulee and Belt Creek drainages of west central Montana are generating a highly acidic effluent containing high concentrations of dissolved metals and salts. This acid mine drainage (AMD) causes stream pollution and has destroyed or degraded the aquatic and riparian communities of these streams. In addition, small areas of farmland have been rendered unproductive by AMD, and water from shallow alluvial aquifers of the area have, in many places, become unsuitable as drinking water sources.

A detailed investigation of the environmental impacts of past coal mining has been completed in order to identify water resource problems resulting from the abandonment of these mines. Both the Sand Coulee and Belt drainages were investigated to determine locations of abandoned coal mining operations and the existence, extent and characteristics of acid mine discharges. Within the affected areas, surficial geology was mapped, and surface water and groundwater resources were investigated. The data gathered and the results obtained have been combined with results of other environmental investigations of the Sand Coulee and Belt Creek drainages to produce a comprehensive master plan for reclamation.

The Sand Coulee and Belt Creek drainages lie in the Great Falls-Lewistown Coal Field. The coal bed in this area consists of several seams separated by thin shale partings, and is of variable thickness throughout the field. The coal seam is in the uppermost section of the Morrison Formation of Jurassic geologic age. The Morrison is underlain by sandstone in the Swift Formation which in turn is underlain by the Mission Canyon Formation.

The Mission Canyon consists of a layered limestone and dolomite. The Kootenai Formation overlies the coal seam in the Morrison and is present at the land surface in much of the drainage. This formation consists of a basal sandstone overlain by mudstone and claystone. Unconsolidated alluvium underlies drainage bottoms in both the Sand Coulee and Belt areas.

The entire Sand Coulee area is drained by Sand Coulee Creek and its tributaries. Groundwater is present in the drainage in Kootenai, Swift and Mission Canyon Formations, and is widely used for stock and domestic purposes. Water quality in most of the streams is fair to poor, and is characterized by a low pH and high concentrations of dissolved salts and metals.

Over 100 abandoned mine adits were located in the Sand Coulee drainage and ten of these were found to be discharging effluent. These ten mines were investigated in detail and a discharge monitoring program was conducted. The total flow of water from all the mines varies from 350 gpm to over 1500 gpm depending on the time of year and the amount of precipitation. Water quality from the mines was consistently poor and flow of AMD from the mines varied considerably. The exceptionally heavy precipitation in May, 1981 was reflected by much greater flows from many of the abandoned mines. Comparison of mine discharge flow rates with a previous study (McArthur, 1970) indicates no significant changes have occurred in the past twelve years in quantity or quality of acid discharge from the mines.

The Belt area is drained by Belt Creek and its tributaries. As in the Sand Coulee area, groundwater is present in the Kootenai Formation and is widely used for stock and domestic purposes. The discharge of mine

effluent, however, is more localized than in the Sand Coulee drainage and is limited to the immediate vicinity of the town of Belt. Three abandoned mines are discharging AMD near Belt and the overall quality of the discharges is characterized by low pH and high concentrations of dissolved salts and metals.

The impacts of AMD in the Sand Coulee and Belt drainages include a significant degradation of surface and groundwater quality in streams. The aquatic community in Sand Coulee Creek and its polluted tributaries is essentially destroyed. In Belt, acid drainage has a serious impact on the fishery in Belt Creek, particularly at low streamflow. An additional impact is degradation of the aesthetic value of streams and channels receiving AMD.

No goals or criteria for successful reclamation of acid mine drainage pollution of surface or groundwaters have been developed and it is difficult to do so. Successful reclamation, therefore, is a subjective value and must be defined in terms of specific water quality objectives. Examples of these objectives are improving the appearance and water quality in streams in the Sand Coulee drainage and enhancement of the fishery in Belt Creek. At low flows in particular, AMD abatement could be of significant value.

A review of many potential AMD control or abatement techniques was made to determine their applicability to the Sand Coulee and Belt Creek drainages. Although a number of innovative and technically sophisticated techniques have been developed for control of AMD, many such problems are simply uneconomical to treat and no cost effective solutions are available.

As a result of this investigation, the abatement or control methods

chosen as being of potential value to the Sand Coulee and Belt Creek drainages have advantages in capital costs, operation and maintenance requirements and costs, and potential risks associated with the method. At-source controls involve the long-term reduction or elimination of the formation of acid drainage while effluent treatment methods deal with treating the AMD itself by neutralization or other type treatments.

Due to uncertainties in future funding of AMD control programs, at-source controls are attractive in that they offer a long-term solution that requires relatively little maintenance. Effluent treatment must be continuous and, if discontinued, the water will return to an acid condition. Hydraulic mine seals appear to have the most potential for effective control of AMD. A field demonstration of this technique at an actual mine site will be an important element in the overall reclamation effort.

The possibility of extensive coal mining occurring in the Sand Coulee and Belt Creek drainages in the next ten years lends an increased importance to understanding existing AMD problems. A demonstration of the feasibility of hydraulic mine seals and further quantitative evaluation of other AMD abatement techniques will make a major contribution to reclamation planning for future coal mining in the area.

B. Aquatic resources

1. Sand Coulee

Six sampling stations for aquatic macroinvertebrates were established in the Sand Coulee drainage and at the confluence with the Missouri River. Problems were encountered with qualitative sampling techniques due to reduced flows and the extent of man-caused disturbances throughout the drainage. As an alternative, multiple qualitative samples were collected at each station in various habitat types to determine estimated percent relative abundance.

The predominant organisms found in the biomass are the true flies, Diptera. The genus Simulium sp. (blackfly) was the most populous organism in the drainage. Dipterans accounted for approximately 50 percent of the organisms present. It is anticipated that a viable benthic community could repopulate downstream areas through natural drift if reclamation improved water quality.

No difference was noticeable between the upstream or downstream sampling locations on the Missouri River. The lower section of Sand Coulee Creek had zero flow for the entire study period. Invertebrates were very scarce at both stations on the Missouri.

2. Belt

Eleven sampling stations for aquatic macroinvertebrates were established in the Belt Creek drainage and at the confluence with the Missouri River. Quantitative samplings were collected during July, August and November, using a modified Surber square foot sampler. Three replicate samples were taken at each station during each sampling period.

Results indicate Belt Creek macroinvertebrate communities are affected by both nutrient enrichment and chronically toxic materials. The upstream

control sample site shows a diverse number of taxà as well as acceptable numbers per sample. Major macroinvertebrate orders present included stoneflies, may flies and caddis flies.

Nutrient enrichment to the stream was most evident at station 4; residential development may affect the reach of stream at this station. The most severely stressed sample site was located at the town of Belt. The reduction in taxa and organisms present indicated classic toxic condition.

Belt appears to be a dividing zone, separating the drainage into two zones. Caddis flies (Trichoptera), generally more tolerant of higher temperatures and sediment loads, predominate the downstream area.

Generally, Belt Creek has a viable benthic population throughout the study area. Seasonal variations indicate the healthiest invertebrate populations are found during the late fall (November). Decreased water use and low water temperatures dilute and reduce toxic conditions.

The Missouri River at Belt Creek had high current velocities, very large substrate, and large flow fluctuations. Conventional quantitative sampling methods were ineffectual. Qualitative sampling techniques resulted in no appreciable difference between upstream and downstream sites. Seventy percent of the benthos collected were caddis flies. No degradation to the Missouri River could be determined.

C. Soils and vegetation

Thirty-two soil sites were sampled and described for laboratory analysis in the Belt and Sand Coulee areas. These sites were selectively chosen as representations of the differing soil conditions. Some sites were chosen to evidence coal spoil contamination; others were chosen because of their natural soil parameters.

Soil samples were analyzed for physical and chemical parameters, including heavy metals. A greenhouse project was designed as a means to develop fertilizer and liming programs for reclamation purposes.

Soils affected by mining tended to be acidic, reddish in color, and barren of vegetation. Heavy metal concentrations were evidenced periodically in some soil profiles; these periodic encounters appeared to be directly related to the presence of acidic conditions. Soils unaffected by mining were neutral, and exhibited viable stands of vegetation.

The spoil and cinder piles were barren of vegetation, very permeable due to an abundance of coarse to gravelly material, and were black or reddish in color.

Soil series were mapped on an aerial photo at a scale of eight inches to one mile. A legend was prepared to correlate the map with the described soil series.

Four vegetation community types were identified during a vegetation inventory conducted in the Belt-Sand Coulee area in September, 1980:

1. skunkbush sumac/bluebunch wheatgrass;
2. mixed grassland;
3. mixed shrub/Kentucky bluebrass; and
4. western snowberry/Kentucky bluegrass.

The skunkbush sumac/bluebunch wheatgrass type generally occupied steep, drier slopes having a southerly exposure. This type had the lowest total percentage vegetational cover of the four communities (33 percent).

Mixed grassland types were found on gentle, well-drained slopes. Vegetational cover was 36.1 percent, slightly higher than the sumac/blunbunch wheatgrass type. The relatively low percentage of canopy cover for these two types was probably due to the low moisture-holding capacity of the well-drained soils upon which they occur.

The mixed shrub/Kentucky bluegrass community was comprised of both moist and dry site species constituents. Upland shrubs occupied the drier sites while more mesic species were found in swales and at lower elevations on deeper soils. Canopy coverage averaged 43.8 percent.

The type designated as western snowberry/Kentucky bluegrass was almost always associated with "tame" pastures and riparian bottoms. This moist type was usually found at lower elevations on deeper soils. It had the highest total of vegetative cover for the four types (61.7 percent).

A species list of all vascular plants encountered during the course of the study was prepared following the nomenclature of Hitchcock and Cronquist (1973).

D. Agricultural practices

The crop-fallow system of agriculture practiced in the northern Great Plains region was introduced in the 1930's. Land cropped under this method is left unplanted for a season to increase stored soil moisture; after being left idle for a year, it is planted to the small grain of choice.

Efforts to conserve soil moisture in this manner result in the accumulation and movement of water high in dissolved salts from the root zone to local discharge areas. This phenomenon is contributing to land management problems in the form of saline seep, causing severe economic losses to farmers.

Acid mine drainage may similarly originate from aquifers located in the strata proximal to abandoned mine sites in the Belt and Sand Coulee areas. Excess moisture exposed to oxidized pyrites in old shafts emerges from the ground surface in a highly acidified state. A likely correlation exists between discharging mines in this area and current land use conservation practices which promote the deep percolation of excess moisture.

Land management and cropping practice alternatives to the current small grain fallow system exist that may serve to retard pollution of underground water. Flexible cropping is an intensive farming method which incorporates a decision to plant that is based on plant available water, expected precipitation and estimated yields. It requires an intensive level of management and special consideration for factors such as tillage practices, weed problems, fertilizer requirements, plant disease and crop selection. Continuous cropping involves planting each spring, regardless of moisture conditions.

Alternate crops such as hay and oil-seed varieties, deep-rooted perennials, native grasses and native sod can be selected which are more efficient users of soil moisture and restrict the deep infiltration of water.

Mechanical practices can be implemented to control excess water and reclaim land disturbed by acid mine drainage. Grass waterways, dikes and terraces can be established at recharge sites to route runoff to areas having a higher drainage potential. Observation wells can be strategically located to monitor fluctuations in the watertable.

The assumption that fallow cropping enhances acid mine discharge is precisely that: an assumption. In order to substantiate a correlation between the deep vertical percolation of water due to fallow systems and acid discharge, it would be useful to develop a working model that incorporates an alternative cropping sequence. If this theory is subsequently proven as valid, the alternative system can then be evaluated for cost effectiveness in comparison to other abatement techniques.

Following preliminary investigations, an alternative cropping sequence can be established that is amenable to that particular operation. The selection of crops to be planted will be based on water extraction rates, suitability to the area in question, soil chemistry and fertility levels, weed and disease control, tillage practices, available equipment, market considerations, and of course, available soil moisture.

Appropriate mechanical practices may also be considered for control of excess water.

E. Air quality

The air quality and meteorology of the abandoned mine lands in east-central Cascade County, Montana were studied in relation to the effect mining wastes might have on the residents and their property. Hythergraphs, using Great Falls data, were prepared to show how monthly precipitation and monthly average temperature varied from the long-term mean values. Although the area has an average yearly precipitation of 15 inches, more than half falls during the months of April through July. An on-site inspection was made of the area in January, 1981 and many sources of fugitive dust were found close to residential areas. The soil from the top half inch of the ash piles was sampled and found to contain significant concentrations of mercury and zinc but negligible quantities of arsenic, beryllium, and copper. About two percent of the surface ash is less than 75 micrometers in size and is available to be blown by the wind as fugitive dust. Suspended particulates were sampled for the months of July and August, 1981. Total suspended particulate concentrations during the period shows an arithmetic average of 64 and a geometric average of 56 micrograms per cubic meter. The composition of the suspended particulate showed significant quantities of zinc and negligible quantities of arsenic, beryllium, and cadmium, similar to composition of the ash. The suspended particulate could not be analyzed for mercury because of a laboratory error.

F. Socioeconomics

1. Sand Coulee

A socioeconomic study of the Sand Coulee area was performed to determine the magnitude of economic ramifications of acid mine drainage, and to identify property owners interested in future reclamation projects. Sources of information utilized in this study include the Cascade County Planning Board and other county officials, Soil Conservation Service, land appraisers and realtors in the Great Falls area.

Mining and agriculture have played important roles in the development of the small communities of Sand Coulee, Stockett, Tracy and Centerville. Approximately 12 miles southeast of Great Falls, the Sand Coulee economy is closely linked with that of the larger city. The area's population peaked during the early 1900's, the years of greatest coal production. Mostly composed of retired individuals or Great Falls commuters, the Eden/Stockett division of the Cascade County census count has remained stable at approximately 860 people for a decade.

Early land use prior to coal mining was almost exclusively agricultural. Land utilized for crop production has been increasing in comparison to grazing and hay land since the late 1800's.

An aerial photograph of the area extending from Tracy to Stockett was compiled (see Exhibit A, Socioeconomic Technical Report). Non-discharging and discharging abandoned mine sites were distinguished. Portal locations are concentrated between Tracy and Centerville, and generally north and south of Sand Coulee.

Present land use includes residential development, agricultural land used

primarily as cropland and agricultural land used for grazing. Most of the abandoned mine sites are clustered near existing communities. Sand Coulee has more mine sites adjacent to it than any other community in the area.

Results of the resident attitudinal survey conducted are included in the socioeconomic technical report. Every respondent indicated that surface water quality was a pollution problem to some degree. However, seventy-two percent indicated they felt no economic loss from any type of pollution. The most popular mitigating measures described reseeding an area after the clean-up of waste piles, and water treatment to clear the surface water. Drilling wells to stop or reduce flows and plugging mine openings were the two most unpopular remedies; almost three quarters of the respondents indicated that they would be against that action.

To determine economic benefit lost due to past mining, the aerial photograph was utilized to arrive at an approximate value of 600 acres of impacted land. Of this 600 acres of agricultural land not in production because of past mining activities, the bulk of it would have been grazing land. The cumulative economic return lost because of unproductive land was derived by utilizing a forty year timeframe (1940-1980). Lost cropland receipts amounted to $53,964; rangeland, $295,800; and accrued interest, $92,800. Total foregone net revenue to farming and ranching operations was $442,566. Residential development added $37,960 to the agricultural net return.

Property values were determined utilizing a resident survey and through interviews with local real estate and appraisal personnel. Recent land sales do not indicate an appreciable difference in value from either residential or farm properties affected by pollution. Using current land

prices in Cascade County, it was calculated that agricultural land would be valued at $141,600 less than other comparable, unaffected lands in Cascade County. Local property owners estimated substantial reduction of home value resulting from the mines, averaging $4,000 per residence. The 1980 value suppression would be $456,000.

Loss of business receipts is proportional to loss of revenues. These cumulative totals are agriculturally related and calculated to be $442,500. For the size of the area and the figurative timeframe, this loss was not considered large. Using 1975 statistics to determine an income multiplier, the cumulative agricultural productivity lost would be $1,279,000, or an average of $32,000 per year for 40 years. This is a relatively minor adverse impact on an annual basis. Detailed descriptions of the formulas utilized to determine economic impact are in the Socioeconomic Technical Report.

Landowners interested in future reclamation projects are listed in the Socioeconomic Master Plan. Landownership information by legal description is included in the socioeconomic technical report.

2. Belt

A socioeconomic study of the Belt Creek area was performed to determine the magnitude of economic ramifications of acid mine drainage, and to identify property owners interested in future reclamation projects.

Located southeast of Great Falls, Belt was incorporated in 1907 and, in its early years, was larger than Great Falls. Mining and agriculture have been dominant forces in the economy. Since the decline of coal mining, the population has declined to around 1600 persons. Predominately composed of retired residents, a substantial number of workers commute to

Great Falls.

To determine the locations and extent of impact to adjacent lands from abandoned mine sites, an aerial photograph was utilized. This aerial is attached as an appendix to the socioeconomic technical report. From the aerial it was estimated that approximately 40 acres in the Belt vicinity are directly impacted by residual mining related land use, concentrated immediately south of the town of Belt.

On the basis of land lost to agricultural production and other uses because of mining related residual impacts, it was estimated that 70 percent of the 40 acres would be grazing or rangeland and 30 percent would be adjacent to Belt and available for residential or community development. Utilizing historic rangeland productivity and per acre values, it was estimated that $20,549 was lost during to 40 year timeframe (1940-1980). Loss of urban land use would amount to approximately $15,184. Detailed explanations of methods and rationale for these determinations are provided in the socioeconomic technical report.

Although unexpected, interviews with realtors and real estate appraisers indicated no appreciable difference in value of either residential or farm properties resulting from pollution from abandoned coal mine sites. Current interest rates and commuting costs were attributed with recent inactivity in the real estate market.

An attitudinal survey was conducted to determine how the Belt community ranked their quality of life with other Cascade County residents. Only three percent of the survey respondents considered themselves worse off than other rural individuals. Using survey results and current agricultural values, it was calculated that this area would be valued $36,624 less than

a comparable unimpacted area in Cascade County. Similarly, residential property value loss is calculated to be $604,000. Detailed explanations for the derivation procedures for these figures are contained in the socio-economic technical report.

The most significant general pollution problems identified by the resident survey were surface water quality, aesthetics and subsurface water quality. Over three quarters of the respondents indicated no pollution had directly effected their property. Total land area of those who indicated they had experienced pollution was small; the largest acreage impacted was 43.5 acres. Specifically requested whether or not they had experienced economic loss relative to the abandoned mines, 90 percent of the respondents indicated they had not. The ten percent experiencing damage mentioned reduced home value and damage to wells, reduced land values, personal health and safety.

A summary of all results is contained in the socioeconomic technical report. The questionnaires are attached as an appendix to that report.

The business dollar impact to Belt and the Great Falls region was agri-culturally oriented and calculated at $35,733. Using 1975 statistics, an income multiplier of 2.89 was derived. Applying this income multiplier to the cumulative lost agricultural productivity results in a total of $103,268, a relatively minor adverse regional impact in the context of the 40 year timeframe.

Landowners interested in reclamation projects are listed in the Socioecomic Master Plan.

VI. Master Plans

A. Hydrology Master Plan

Contents

A. Hydrology Master Plan

1. Introduction

The Sand Coulee and Belt Creek drainages in west central Montana contain over one hundred abandoned coal mine adits. Approximately thirteen of these adits are discharging effluent that is polluting surface water and groundwater resources. Specific impacts include degradation of surface water and groundwater quality and increase in flow. Water quality impacts on streams generally are severe. Most streams in the Sand Coulee drainage are rendered unfit for domestic, stock and irrigation use and the aquatic communities are essentially destroyed. Belt Creek has suffered a degradation of water quality below the discharging mines. The aesthetic values of the stream channels in the Sand Coulee and Belt areas have also been adversely impacted. Many stream bottoms are covered with a thick iron precipitate and the water is discolored and turbid. The objective of this investigation was to develop a comprehensive understanding of water resource problems and to determine feasible techniques to abate or eliminate adverse water resources impacts caused by AMD.

2. Methods for control of AMD

A great deal of technical effort has been directed at control of acid mine drainage from abandoned coal mines in the United States. Although a large number of innovative and technically sophisticated techniques have been developed for AMD control, the application of these techniques to specific acid drainage problems has met with mixed success. Many AMD problems are simply uneconomical to treat and no cost-effective abatement techniques are available.

All techniques for control of AMD can be divided into three basic categories. They are:

1. effluent control
2. mine manipulation
3. infiltration control

As part of this project, a review of a large number of potential control or abatement techniques were made to determine their applicability to the Sand Coulee and Belt Creek drainages. Of the approximately fifty techniques reviewed, a total of eight were selected as having potential application in control of mine specific AMD problems.

What were the original 50 techniques?

a. Effluent control

The objective of effluent control techniques is to improve effluent quality so it can have a beneficial use. The most common methods for treatment of effluent are neutralization with limestone or lime to reduce acidity and precipitate metals. Other treatment techniques include separation of dissolved pollutants such as metals and salts from the water. This can be accomplished by a wide variety of methods. All these techniques depend on the chemical or physical treatment of the effluent to remove selected dissolved constituents. This process normally creates sludge that is separated from the treated water. Other widely used techniques for effluent control are ponding of effluent to allow seasonal evaporation, and ponding of effluent with subsequent mixing of higher quality waters. This adds oxygen to the system which may be beneficial in precipitation of dissolved metals. Effluent can also be diluted by regulation of streamflow using water released from impoundments, or by supplementing streamflow by groundwater or water imported from other basins.

b. Mine manipulation

Another major technique in controlling acid mine water is to alter the mine workings themselves to reduce the flow of effluent or to improve

the quality of effluent existing from the mines. This commonly is accomplished by flooding the workings with water to exclude oxygen thereby reducing the rate of acid formation. Other materials can also be used to fill the mine and reduce the rate of reaction and accessibility of oxygen and water to oxidizing pyrite material. Potential mine manipulation techniques for the Sand Coulee and Belt drainage are:

1. construction of dams and flooding of the mines;
2. sealing the mine portals to flood the mines and eliminate or reduce effluent flow;
3. backfilling the underground workings with waste material to reduce contact with oxygen and pyritic material and reduce effluent flow.

c. Infiltration control

where & when?

This technique has been used successfully with some AMD problems. The objective is control of infiltration into the mine workings by modification of the land surface above the mine. Specific techniques that have been used include creation of a relatively impermeable layer, utilization of water-consuming plants, sloping the land surface to increase surface runoff, or rerouting drainages to avoid concentrations of water on the land surface above the mine. Another technique that has been used for infiltration control is removal of groundwater from the aquifer supplying water to the mine by means of wells or infiltration systems. All of these techniques reduce the amount of water entering the mine workings and reduce the quantity of water exiting the working.

3. Feasibility of AMD control methods

Mine manipulation and infiltration control techniques are at-source abatement methods. They involve prevention of, or reduction in, formation of

pollutants, while the effluent control techniques involve treatment of the acid drainage itself. The selection of an appropriate control method depends upon desired results, capital costs of the method, operation and maintenance requirements and costs, environmental impacts, and potential risks associated with the method. At-source controls are designed to provide long-term reductions in the formation of acid mine drainage. Effluent treatment methods are designed to achieve a water quality goal and normally require continued operation and maintenance efforts to achieve desired results.

Of the eight control techniques considered for the Sand Coulee and Belt area, five are at-source control and three are effluent treatment techniques. In this section each potential control method is considered, including its applicability, cost, benefits and impacts.

a. Streamflow regulation

In the Sand Coulee Creek drainage, a potential technique for improving water quality would be storage of water (from good quality streams) in holding ponds or reservoirs and release of stored water during the low flow season. The effect of this release would be the dilution of mine waters during the low flow when streams are significantly affected by acid drainage. It is highly doubtful, however, that such dams could be economically justified on the basis of AMD control alone. The cost-effectiveness of large dams for control or abatement of AMD cannot be determined. If future dams are considered for the drainage, then streamflow regulations should be considered as one of the potential benefits of the stored water. Streamflow regulation has been shown to be effective in reducing the impacts of AMD during low flow periods and could be effective in the Sand Coulee drainage.

In the Belt drainage there has been no consideration of dam sites and there is little potential that major impoundments would be considered in the vicinity of the abandoned coal mines.

b. Evaporation ponds

Large evaporation ponds are commonly used for disposal of waste waters. Acid mine drainage would need to be collected and conveyed to a pond, or series of ponds, and the water would then be lost to the atmosphere through evaporation. No discharges to surface or groundwater would occur. The bottoms of these ponds would need to be lined where the impoundment bottom is permeable. The system would be designed to have the capacity to evaporate the natural precipitation entering the pond and the inflowing mine waste . These ponds would periodically require cleaning and solids would need to be removed and transported to a suitable burial site.

There are several important considerations in the use of the evaporation technique. In Montana evaporation is restricted to the warm portion of the year and it commonly is assumed that from November through April no evaporation occurs. This requires storage of all the water from the mine and natural precipitation during this six month period. Each gallon per minute of water flowing from an abandoned mine for a six month period requires approximately 260,000 gallons of storage. This is a large storage requirement and would necessitate a large, relatively flat area for pond placement. The high construction cost and necessity for a relatively flat area restricts this technique to mines with small outflows.

Costs of constructing an impounding structure, including materials, compacting, and grading is estimated to be approximately \$1.50 to \$2.50 per cubic yard. Mining costs depend on the type of material used and the area covered. Assuming a continuous mine discharge of 5 gpm, an evaporation

pond system would require about four acres of land and would cost from $30,000 to $100,000. Cost is very dependent upon the need for an impervious liner. This analysis does not include the cost of land purchased, piping, easements, legal and engineering services. Evaporation ponds also require annual maintenance including inspection and repair of the dikes, piping systems, vegetation control and periodic removal of the evaporated solids.

Evaporation ponds could work for very small flows of AMD, but initial costs are high, land requirements are large, and seepage control would be costly.

c. Neutralization

Neutralization of acid mine drainage by lime and limestone is probably the most widely used technique for water treament of acid mine waters. Many substances have been considered for neutralization, including lime, limestone, caustic soda and flyash. It has been found that, for most applications, lime and limestone are by far the most cost-effective materials. Limestone and lime neutralize acid, increase pH and alkalinity and precipitate many metals including aluminum, iron and manganese. A conventional lime or limestone neutralization process consists of a reactor, aerator, settling tank, and sludge thickener. The neutralized water is returned to the stream.

Another method for limestone treatment is the use of a rotary drum filled with limestone. Stream water rotates the drum and the water is partially neutralized during flow through the drum.

A neutralizing facility can be established at the mine along a stream or at a central location for collection of AMD. The facility is designed for a specific flow range and flows less or greater than the design flow are less efficiently handled. A lime or limestone treatment facility is

essentially a chemical processing plant that must be properly designed, constructed and operated to adequately neutralize acid water. The plant must function in the Montana winter environment and under a variety of acid loads and flows. To provide continuous neutralization, the plant must be operated continuously. If neutralization stops, the effluent would quickly become acid.

All mine effluent in the Sand Coulee and Belt Creek drainages can be successfully neutralized using lime or limestone, however, the cost and long-range success of neutralization must be considered. McArthur (1980) examined costs of neutralization in the Sand Coulee drainage. He estimated the operating costs for a 750 gpm conventional limestone neutralization facility to be about $223,000 per year. This did not include costs to convey acid water to a central treatment point. A revolving drum facility was estimated by McArthur to have capital costs of $11,140 and an annual operating cost of $7,240 per year to treat 40 pgm. It can be safely assumed that present day capital costs for these facilities would be much greater than estimated by McArthur. Lime neutralization costs have also been estimated by the EPA (1973). The plant cost is estimated to be about $245,000 for a 500 gpm plant and operating costs are about $450,000 per year

Limestone or lime neutrailization does not provide a permanent solution to acid mine drainage unless operated continuously. There seem to be no potential instream benefits in Sand Coulee Creek or Belt Creek that would justify the large capital and operation costs of neutralization facilities.

d. Dam and flooding

The use of small dams to inundate and flood abandoned mines theoretically would reduce oxidation of pyrite in the mines and improve effluent quality. This technique has not been demonstrated to determine its feasibility and

effectiveness but is theoretically sound and could have potential application to AMD problems. Sand Coulee Mine #5, located in a small side tributary of Sand Coulee, near the community of Sand Coulee potentially could be flooded by placement of a small dam in its drainage. This coulee is isolated, narrow and has bedrock exposed on the coulee sides. McArthur's 1970 estimate of the equivalent annual cost of this dam was $1,800. This cost would now be much higher. Other mines in the Sand Coulee Creek drainage could also be flooded by placement of large dams including those upstream from Sand Coulee and those on Cottonwood Creek. The use of large dams for flooding, however, would not be a cost-effective technique. Multi-purpose dams in the drainage possibly could be considered for flood control and recreation. Mine flooding potentially would be an additional benefit. There is no opportunity for flooding of discharging mines in the Belt area.

e. Mine sealing

There have been a number of demonstrations of the effectiveness of mine sealing. It has emerged as a suitable technique, and, more importantly, a permanent technique for controlling acid drainage. Mine sealing techniques generally are divided into air seals, which involve sealing of all openings into the mine through which air may enter, and hydraulic seals, which essentially impound water and flood the mine. Air seals have had poor success. It has been found that air continues to enter the mine workings in spite of the seal. In the fractured rocks associated with the mines in the Sand Coulee and Belt area it is doubtful that air sealing would work. The rapid movement of natural groundwater into these mines suggests that air also could move through the fractures into the mine.

Hydraulic seals are used when it is desired to eliminate the discharge of water from the mine opening. This type of seal impounds water within

the mine workings and reduces the rate of acid production. This seal, along with an outcrop barrier, must withstand the maximum hydraulic head generated if the seal is to be successful. A number of types of hydraulic seals have been developed and tested, including double and single bulkhead, concrete, gel, clay and grout bag seals. The selection of an appropriate seal depends on a large number of variables including, characteristics of the underground mine opening, strength and permeability of the wall, floor, and roof rock, operation and maintenance costs and hydrostatic pressure. The best seal technique can be selected only after careful hydrological, geotechnical and geological evaluation of the specific mine. None of the mines near Belt or the Sand Coulee drainage have had adequate technical investigations to allow selection or design of a hydraulic mine seal.

f. Seals using mine backfill

There has been considerable interest in the removal of coal mine wastes in the Sand Coulee and Belt areas and placement of these wastes into abandoned mines. Such wastes alone would not be a suitable mine seal. These wastes potentially could be incorporated into or combined with other materials such as cement to provide the overall performance needed in a hydraulic seal. Mine wastes also could be placed into abandoned mines behind single or double bulkhead hydraulic seals. Generally, however, backfilled mine wastes are not of significant value for use as hydraulic seals.

The cost of mine seals obviously depend on the individual mine requirements and the sealing technique selected. The costs of some typical hydraulic seals will provide some insight into potential costs for the Sand Coulee and Belt areas. Costs of grouted, double bulkhead seals at abandoned mines in Pennsylvania were estimated to average $21,000 in 1974, including all contractor and material costs. Reinforced concrete seals cost $15,000 to $20,000.

Grouting to reduce the possibility of seepage around the seal is estimated to cost $25 to $80 per linear foot of grout curtain (EPA, 1973). Single bulkhead seals range in cost from $6,000 to $21,000 each and clay seals range from $4,000 to $12,000 per seal (EPA, 1973). If suitable, and if successful, hydraulic seals offer the potential for long-term control of acid drainage at a reasonable cost. Much mine-specific work must be completed to determine the potential for application of hydraulic seals to mines in the Belt and Sand Coulee areas.

g. Overburden water removal using wells

Wells are widely used for removing water from aquifers intercepted by underground or open pit mines. The objective of dewatering is to remove groundwater before it enters underground mine workings. Two techniques could be used to remove water from the Kootenai Formation overlying the coal seams in the Belt and Sand Coulee areas. The first would be to drill wells into the basal sand or conglomerate in the Kootenai Formation and pump groundwater to the ground surface. Another option is to construct connector wells. These wells would extend through the Kootenai Formation and through the coal seam of the Morrison Formation into an underlying aquifer. The objective of these connector wells would be to allow groundwater to enter the well in the Kootenai Formation and move downward through the well into the underlying aquifer. Connector wells essentially act as a short circuit to allow groundwater to move from the Kootenai Formation to an aquifer beneath the coal seam. This could possibly reduce water inflow to the abandoned mine workings. Wells utilized to pump groundwater to the land surface pose a number of problems including, the effort and cost required to construct the wells, connection of the wells through a piping system, supply of power for the pumps and disposal of pumped water. Another problem with this technique is that dewatering of the Kootenai

Formation may also impact springs and wells present in the Kootenai near the dewatering area. This technique requires detailed knowledge of the location of all underground workings.

Both of these dewatering techniques require construction of a large number of wells and periodic inspection and maintenance would be necessary to insure their continued proper operation. If water is pumped from the wells, a complex and expensive piping and pumping system would be required and there would be a continuing cost for groundwater removal. A computer model was used by Schubert (1978) to estimate the effectiveness of dewatering wells and removal of water from underground workings overlain by a permeable sandstone. Conclusions of this computer simulation were that a significant reduction of flow rate into the mine would not be feasible under the geologic, hydrologic and mining conditions identified in that study. There have been no on-the-ground demonstrations of this technique. Cost of groundwater dewatering is unknown and costs cannot be determined until the hydraulic tests are conducted on aquifers in the drainage.

h. Vegetative evapotranspiration

A potential application of the technique of vegetative evapotranspiration to AMD would involve determination of the drainage area contributing to the underground mines and planting of high water-use crops or continuous cropping in the infiltration area. This technique has never been attempted for abatement of AMD, however, its success in Montana in saline seep reduction suggests it could be an effective control technique. The disadvantages of vegetative evapotranspiration include the requirement for changes in cropping patterns, sustaining the crops during drought periods and the difficulty in locating areas of infiltration contributing to underground mine workings. These are all formidable problems. Mine sites

The use of high water use crops for control of saline seeps has been applied most often to the seep areas (i.e. effluents) as opposed to infiltration areas.

that have significant farming activity in their potential areas of infiltration are Sand Coulee mines SM2, SM3, and SM4 and Belt mines BM1 and BM2. If vegetative evoptranspiration is to be attempted, these mine areas should be considered. It is interesting to note that Sand Coulee Mines SM2 and SM4 contribute about 80 percent of the entire pollutant load in the Sand Coulee drainage and Belt Mine BM1 contributes about 80 percent of the pollutant load in the Belt area. Application of this technique requires detailed information on location and extent of underground workings, determination of the infiltration rate ~~are~~ overlying mine workings and potential cropping patterns that would increase evapotranspiration losses. This program also would require an intensive monitoring system consisting of measurement of soil moisture, precipitation, and mine effluent flow and quality.

4. Summary and conclusions

No goal or criteria for success have been developed for the Sand Coulee and Belt acid mine drainage problems, nor is it easy to do so. Streams affected by acid mine drainage in the Sand Coulee Creek drainage are intermittent or ephemeral and probably could not support a fishery if AMD were eliminated. The AMD effected streams are not used for drinking water or irrigation. It is very doubtful that these streams in the future will be useful or needed as sources of domestic or public water. If AMD were abated, the stream could possibly be used for irrigation, particularly if water storage facilities were constructed in the drainage. Abatement of acid mine drainage probably would improve the appearance of affected streams. In the Belt area, Belt Creek supports a fishery. Abatement of AMD would improve water quality and probably would result in a healthier aquatic community and improved fishery. At low flows particularly, AMD abatement would be of significant instream value in Belt Creek. Improvement of water quality also would improve the appearance of channels impacted

by AMD.

It is probable that there are no cost effective solutions to existing AMD problems in the Sand Coulee and Belt drainages. Results of the extensive investigation of existing AMD problems in these areas shows there are no economical alternatives to restore streams to their former, unpolluted condition. Past mining practices in the Sand Coulee and Belt areas obviously have created a significant water resource problem and will persist for many decades.

The present availability of federal and state funding to correct existing AMD problems is of major importance. These funds should be used to test the feasibility of AMD control at abandoned coal mines. Of particular importance is to demonstrate the feasibility of long-term solutions to existing AMD problems. At-source control measures considered to have potential application to abating or eliminating AMD in the Sand Coulee and Belt areas are hydraulic mine seals, vegetative evapotranspiration and overburden water removal using wells. These control methods, once implemented, require relatively little maintenance and operating costs are low. Mine hydraulic seals in particular have been used in many mines and in some cases have been found to be a low cost, long-term solution to AMD. Hydraulic seals deserve detailed evaluation for application to mine specific problems in the Sand Coulee and Belt areas. A field demonstration of a hydraulic seal at a mine site would be important in development of AMD control in Montana. THe use of connector wells and vegetative evapotranspiration are completely untried techniques and are less attractive as potential solutions to AMD. These techniqeus can, in theory, work and should be further evaluated for feasibility demonstrations at specific mine sites.

Effluent treatment techniques involve high capital costs, and are complex and expensive to operate and maintain. The long-term use of treatment techniques for solving AMD problems seems inappropriate in that long-range funding is uncertain and continued operation and maintenance of treatment facilities cannot be assured.

Mining of high sulphur coal from the Great Falls-Lewistown coal fields could occur in the next ten years. Coal exploration drilling is underway at several sites and the Montana Power Company has announced Great Falls will be the site of a large coal-fired steam electric generation plant.

A technical deomonstration of the feasibility of hydraulic mine seals would be of significant value in design of appropriate post-mining water resource protection measures. Similarly, detailed technical evaluations of other at-source control techniques and effluent treatment methods for specific mine sites should be made to determine if a field demonstration of feasibility should be conducted. The hydrology and AMD control efforts conducted to date provide an excellent background for implementation of mine-specific AMD solutions in the Sand Coulee and Belt areas and also provide a good framework for planning future mines in the Great Falls-Lewistown field.

SOILS AND VEGETATION MASTER PLAN

B. Soils and Vegetation Master Plan

Contents

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B. Soils and Vegetation Master Plan

1. Introduction

a. Goals and objectives

Objectives of soil and vegetation reclamation in the Belt and Sand Coulee area include:

1. Eliminating acid production and discharge;
2. correcting slope instability;
3. improving production by increasing ecosystem stability;
4. reducing negative aesthetic impacts.

Soil and vegetation reclamation efforts can be undertaken only after acid mine discharge is eliminated on those sites where it now exists. Once spoil piles are removed and the soils beneath those piles are vegetated, the remaining three objectives can be realized.

Post reclamation land use will primarily be directed toward livestock grazing. Other land use considerations include farming, residential use and wildlife.

b. Report organization

The reclamation of abandoned mines in the Belt-Sand Coulee area is a complex process of integrating ameliorative techniques from disciplines which address soil, plant and water relationships. The rehabilitation of soils is totally dependent upon the eradication of acid discharge on those sites where it exists. Similarly, revegetation of disturbed areas cannot occur until a soil medium conducive to plant growth is established.

The soils/vegetation reclamation portion of the Master Plan follows the hydrological section. This ordering of subject material is presented in a series of four matrices designed to: 1) describe site specific physical

characteristics; 2) define various abatement techniques and their considerations; 3) present priortized site-specific abatement methods and costs; and 4) describe reclamation components. A thorough discussion of abatement techniques and considerations precedes the matrices.

2. Abatement techniques

Nine abatement techniques are presented as a part of the comprehensive Master Plan. These alternatives can be adopted locally to restore disturbed land to pre-mining conditions.

a. Pneumatic injection

Depositing wastes in the old mine shafts by a pneumatic conveyance system for abrasive materials is a relatively new reclamation technique. This system uses low pressure, high volume air traveling at high velocities to transport materials up to three inches in diameter. It is capable, under ideal conditions, of delivering 100 tons of material per hour through a pipeline for a distance of 500 feet. reference? Abrasive materials moved by this system include native soils, waste mine rock, crushed rock, salt, metallic ores, and coal. Cement, bentonite, or other additives can be mixed with the waste material to insure compaction and stability. This method of mine reclamation can be used to prevent subsidence of old mine shafts and act as a sealant to the adit.

Reclamation work performed by one corporation, EBY Enterprises of Kent, Washington, has proven successful at both Greensburo and Masontown, Pennsylvania. In Armington, Montana, a pneumatic system constructed by a Belt contractor was used to deposit derelict coal slag approximately 200 yards back into an adit. The adit was sealed and the buried soil was covered and fertilized. Maintenance of the amended soils may be necessary for some years in the future.

A limitation of the pneumatic system for depositing waste into derelict mines is the presence of acid drainage. If a mine happens to cross or exists as an aquifer, acid water drainage may occur. Redepositing mine tailings into a "wet" adit would allow the source of acidity, which is the highly enriched iron pyrite coal slag, to increase. This compounds an already complex hydrogeological problem. Interim solutions have been proposed which include adding large quantities of lime or bentonite to the coal slag when deposition takes place. These solutions only alleviate the problems for a finite amount of time and to an unknown degree; it seems apparent that wet adits should not be used for deposition of coal slag until the hydrological problems are solved.

Slag and cinder piles located in front of wet adits should be hauled to those shafts or adits that are dry and offer sufficient size to hold the extra waste material.

b. Alternative use of material waste

The use of waste piles for commercial products other than fill is very limited. Most of the coal slag piles are contaminated with overburden material, which is the reason the coal was initially discarded.

Cinder piles are used for local high school running tracks, private driveways, Malmstrom Air Base roads, and area gravel roads. Cinders in the Stockett area is sold for up to $4.00/cubic yard.

Mr. Ralph Singles, operator of a ranch in Number Five Coulee, maintains that the black color of the waste and its high rate of permeability keeps his driveway clear of snow and dry throughout the year. Gob piles used for fill, whether cinder or coal, retain the potential for causing acid

drainage. Acid produced would probably be much diluted due to the decreased concentration of the iron pyrite which is characteristic of these waste piles. The acid-producing properties and the occasional concentration of toxic heavy metals should be considered before these materials are used for commercial products.

c. On-site burial of wastes

Burying wastes on site is a viable alternative from an aesthetic as well as a safety and health viewpoint. This alternative is basically accomplished by either of two methods; encasements or single mass burial.

When existing problems include heavy metal toxicity and possible contamination of adjacent soils, an encasement of the soil is best. This method segregates the spoil materials into separate "cells", with a series of cells all the same height to make up a "lift". A soil cover layer is incorporated between each lift. This concept of burial is basically designed for sanitary landfills but would be an applicable mitigative measure for the Belt or Sand Coulee area. A method of burial which displays the use of non-soil and soil liners is shown in Figure 1.

To minimize the surface area and cover material required when this method is utilized, side slopes should be designed in the 20 to 30° range (Fuller, 1980). Most of the spoil piles in the Belt/Sand Coulee area do not exhibit a toxic heavy metal problem; in this case, encasement, a costly process, is not required. For spoil piles with low toxicity, burial and cover is adequate. Contact with water may create an acid problem downslope or beneath the buried spoils, possibly into the watertable. Figures 2 and 3 graphically present the general process on a flat site and on a slope.

Liners and covers are an integral part of any consideration of burial and

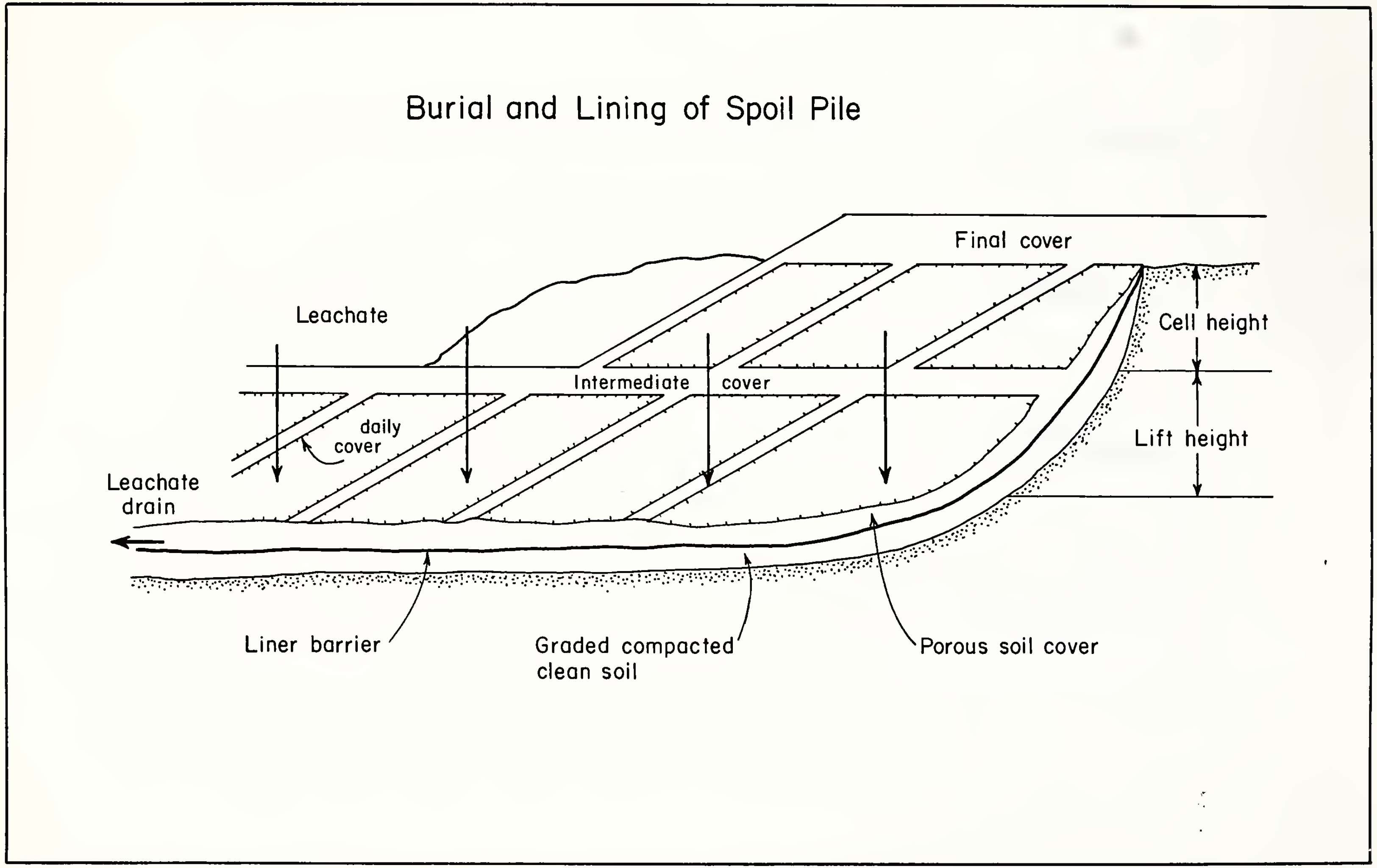

Fig. 1. Burial and lining of spoil pile using artificial or soil liner burial (After W.H. Fuller).

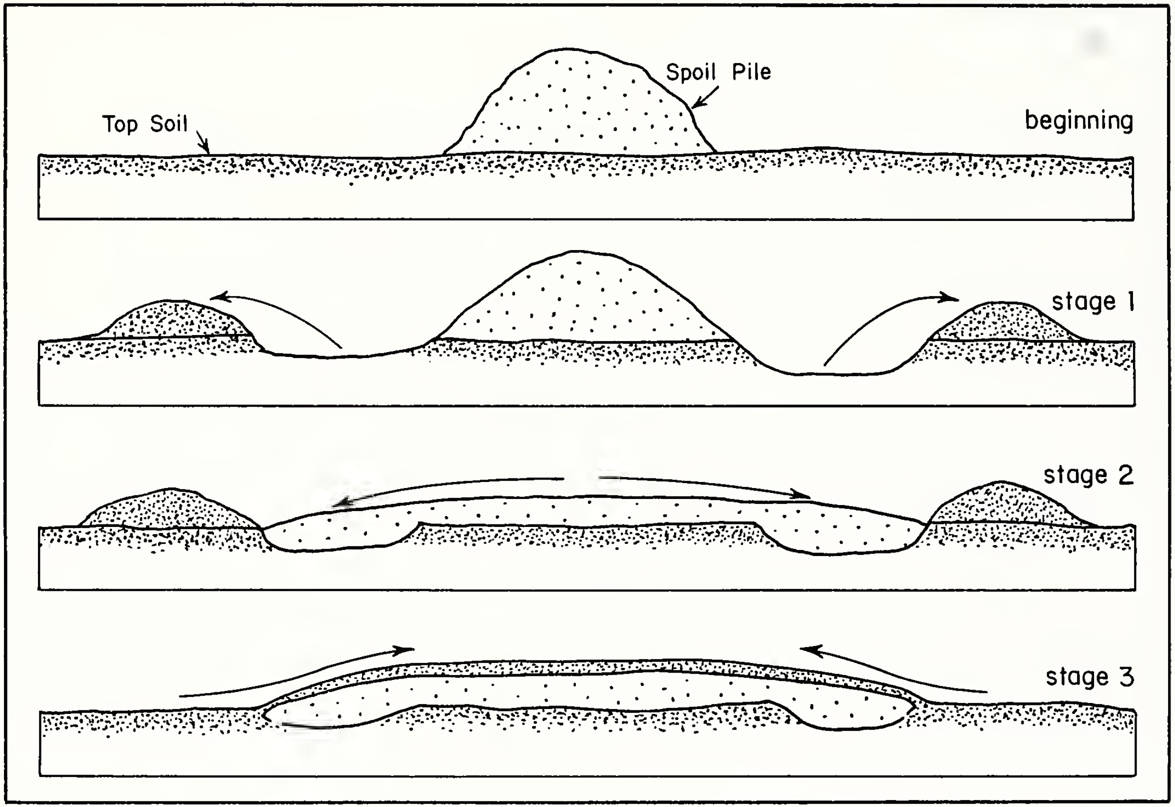

Fig. 2. Burial of spoil pile on flat site.

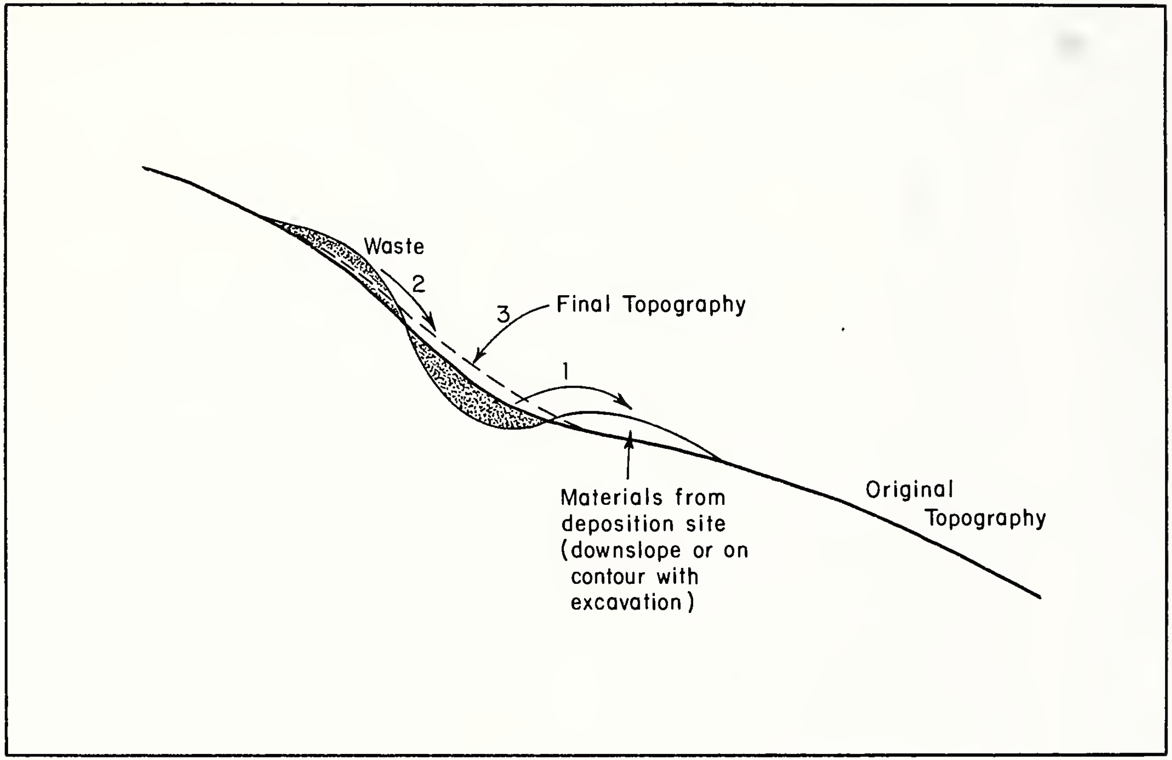

Fig. 3. Burial of waste materials on a slope.

containment of wastes. Care and maintenance must be provided to eliminate toxic metal migration to surrounding soils when liners are used. When a cover material is used to contain wastes and provide a seedbed for vegetative plantings, a scheduled maintenance and monitoring program must be initiated.

Soil is usually the most abundant and accessible material utilized as cover. Its value is derived from its potential importance as a planting medium as well as its aesthetic features. There are many factors to consider in ranking a soil's cover quality: 1) texture; 2) water infiltration and penetration; 3) gas exchange rate; 4) erodibility; 5) fertility and productivity; 6) water-holding capacity; 7) shrink-swell capacity of soil clays; and 8) chemical limitations (Schafer, 1979). Guidelines for rating cover material are presented in Table 1.

Economics usually dictate the use of soils closest to a project; therefore, soils with some limitations will probably be used. Amendments should be applied to rectify any limitations. Because of acidity of the spoils and plant requirements, an effective thickness in cover must be established. Since topsoils on Montana rangeland are relatively shallow, achieving an "effective depth" usually means utilizing some subsoil. A topsoil layer must be at least 10 cm thick to be effective. This depth will only be sufficient to provide a good seedbed and moderate store of nutrients for subsequent growth. A grassland requires a depth of at least 25 cm to be totally self-sufficient; trees require a far greater depth.

Schafer recommends a minimum depth of 15-30 cm over high quality spoils with 75-100 cm minimum over materials unproductive to plants. This is only a minimum recommendation and must be carefully considered if toxic materials are present beneath the cover soil.

Table 1. Guidelines for rating cover-soil material for reclamation use (after W.M. Schafer, 1979).

Factors Affecting Suitability of Soil Material	Good	Fair+	Poor++	Methods
Texture class	vfsl, fsl, sl, l, sil	lfs, ls, cl scl, sicl	s, c, sc, sic	ASA Agron. Mono. Methods of Soil Analysis II. 75-4 pp.1062-1063
Moist consistence	vfr, fr	lo, fi	vfi, exfi	Soil Survey Manual. p 233
EC (mmhos/cm)	<4	4-8	>8	USDA Hndbk. 60. pp. 88-89
ESP	0-5	5-15	<15	Soil Survey Investigations. Rpt. 1, pg. 21, Method 5D1
pH	5.6-7.8	4.5-5.6: 7-8-8.4	<4.5, >8.4	Soil Survey Investigations. Rpt. 1, pg. 59. Method 8cla. Use indicator dyes for field estimate
Stoniness class	0	1	2-5	Soil Survey Manual. pp. 217-219.
Available water	>10	5-10	<5	Soil Survey Investigations. Rpt. 1. pg. 14 Method 4C1
Rock fragments (%)	<15	15-35	>35	Estimate
Saturation water (%)		25-80	<25; >80	USDA Hndbk. 60. pg. 84 Method 2, 3a

+ Mitigation of adverse properties will increase reclamation potential

++ Materials rated as poor may be suitable as topsoil only if adverse factor can be treated

Clay content and the associated CEC (Cation Exchange Capacity - the principal site of soil nutrient storage) are very important and must be considered if the soil to be used is extremely sandy. Improved agricultural yields were reported in soils containing greater than 15 percent silt and clay (Knabe, 1969). This is probably correlated to both CEC and the consequence of heavy metal ion attenuation being negatively correlated to sand but positively to clay.

Because clay is the primary mineral controlling chemical activity in the soil, it may be necessary to import a clayey soil for mixture if only sandy soils are available as cover material. Clays are not as important as pH is in affecting heavy metal migration, but they are critical; therefore, minimizing pollutant migration may involve the manipulation of soils to alter textures (Fuller, 1980).

Cover soil stability is critical during the period from application until successful vegetation establishment and adequate root development insure minimum soil erosion. Reclamation plans must include soil stabilizers (mulches) where rains may be heavy, extreme gradients exist, or where sandy soils, which are very susceptible to wind erosion, are encountered. Mulches are used as a temporary surface protectant that require no maintenance. If applied correctly, they can be an inexpensive part of the total reclamation package. The variety of materials in this category are quite expensive; they are presented in Table 2.

Establishing a monitoring schedule is critical to check the effectiveness of toxic metal attenuation. Slope stability must be maintained to insure that further efforts are not required because of mitigative measure failure. The monitoring procedure should include periodic analysis of

Table 2. Mulches and stabilizers suitable for reclamation purposes (after Bradshaw, 1980).

Material	Rate (tons/ha)[1]	Persistence	Stabilization	Soil-water Retention	Nutrient	Toxic
Mulches						
excelsior	4	moderate	moderate	moderate	none-low	none-low
wood shavings	4	"	none-low	none-low	"	"
wood chips	10	"	"	moderate	"	"
bark shredded	4	high	"	"	"	"
peat moss	2	none-low	"	none-low	"	"
jute netting	-	moderate	high	"	"	"
corncobs	10	high	none-low	"	"	"
hay	3	none-low	"	"	"	"
straw	3	moderate	"	"	"	"
fiberglass	1	high	moderate	"	"	"
Stabilizer/mulches						
wood cellulose fiber (as slurry)	1-2	moderate	high	none-low	none-low	none-low
sewage sludge (as slurry)	2-4	none-low	moderate	"	"	"
Stabilizers						
asphalt (as 1:1 emulsion)	0-75	none-low	moderate	none-low	none-low	none-low
latex (as appropriate emulsion)	0-2	"	"	"	"	moderate
alginate or other colloidal carbohydrate (as emulsion)	0-2	moderate	"	"	"	none-low
polyvinyl acetate (as 1:5 emulsion)	1	"	"	"	"	"
styrene butiadene (as 1:20 emulsion)	0-5	"	"	"	"	moderate

[1] rates can be varied depending on circumstance - will affect soil water capture and retention and seedling establishment.

subsurface water quality and an investigation of the rate of soil erosion. It may be necessary to line an excavation prior to filling with waste material to prevent leaching toxic constituents into surrounding soils. Where water infiltration is not a problem, this is not necessary as long as an adequate plant cover is established to utilize normal precipitation. Without plant utilization, water may accumulate in the subsoil and underlying waste. Water is a transport medium for heavy metals; a liner should be considered for any site threatening to drain water beyond the cover material and into surrounding soils.

Native soil, clays, or fabricated chemical barriers can all be considered as liners as long as they maintain structural integrity. Where fabricated chemical barriers are not available or feasible, the soil itself can be modified to serve as a barrier. Material stockpiled during excavation often is utlilized as a liner. The usefulness of soil as a liner is based upon its chemical and physical nature. Criteria for a soil's usefulness as an effective sealer have been developed by Fuller (1979): Clays are preferred which have a 1:1 ratio of nonexpanding lattice structure. These clays have a low coefficient of liner expansion (C.O.L.E.) or shink-swell capacity. Since they will not shrink and crack as will 2:1 clays (montmorillonite and bentonite), leachate is prevented from flowing through the liner. Under constantly wet conditions, montmorillonite clays may be of greater effectiveness since they will swell and form a very impermeable layer. Successful utilization of bentonite requires exacting conditions in most locations.

Natural fine-textured soils, with at least 20 percent clay and 15 meq/100g CEC, excavated on site are suitable for a liner. Wetting the soil to 40 percent of its normal field water-holding capacity helps to achieve the recommended level of compaction, 10^{-6} cm/sec. Depending on clay content,

a lining of 15-60 cm has been suggested. With minimal compaction, soil barriers ranging from 1 to 1.5 M (4-5 ft) may be successful to minimize pollutant migration.

An additional recommendation is that the layer of soil be at least 1.5 m (five feet) above the annual average level of the watertable.

For soils designed to allow some migration of trace and heavy metals, crushed limestone and organic wastes may be used along with soil liners.

Soil may also be mixed with lining materials such as cements, asphalts, lime, rubber and plastic latexes, and penetrating polymeric emulsions.

Asphalt, concrete, rubber or plastics can also be used as liner material. Acidic conditions will shorten the effective lifetime of such materials. Covering an impervious barrier with a porous soil and establishing a graded and compacted soil base beneath the liner has been suggested as one method to increase the life expectancy of such materials (Haxo, 1976).

d. Off-site burial of wastes/commercial distribution

Coal slag or cinders can be hauled to a centralized location for burial or for distribution as a commercial product. The site chosen for storage should be examined prior to use to check for potential environmental or health hazards.

Any site chosen must not have any contact with groundwater or with surface water. The site must be sealed on all sides and monitored for defects in the seal on a routine basis.

Because of the potential for groundwater and surface water contamination, burial sites should not be located on a floodplain or a coulee bottom.

A high terrace or ridge top above any groundwater or surface water may provide an acceptable site location. A scheduled maintenance program to monitor groundwater and surface water quality should be implemented. Vegetative cover should be periodically assessed.

A seal should be placed under the spoil pile and a settling pond placed downhill from the spoil pile. The seal and the pond should be maintained and monitored so that all water seepage, drainage, or runoff is eliminated or caught for treatment.

When the commercial inventory is diminished, the underlying seal should be broken and the settling pond should be chemically treated. Reclamation procedures recommended for spoil piles should be instituted at the storage site.

e. Chemical abatement and fertilization

Adverse chemical and physical properties present in the spoil piles can be rectified on-site only after costly application of ameliorative products. Liming, dilution with silty or clayey soils (or an equivalent artificial substitute) and/or fertilization (nitrogen, phosphorus, and potassium and other macro-micro nutrients) can be applied. The acid soils beneath the spoil piles can be mitigated with proper utilization of liming and fertilization, excluding those sites affected by acid drainage.

Applications of chemical additives, such as lime, are used to negate soil constituents which are hazardous to living organisms (chemical abatement) or to enhance the soil's capability to support life by addition of supportive nutrients (fertilization). Because of the adverse effect low pH has on plant communities, causing an increase in heavy metal solubility, liming is recommended as the chief amendment for abatement in the Belt/Sand Coulee area.

Although rates of neutralization and final results are difficult to predict with certainty, it is known that the reaction of liming materials with neutralization of H^+ ions in the soil solution begins with either OH^- or SiO_3 = ions furnished by the material. Liming material's basic reaction can be illustrated with $CaCO_3$, which acts in water as follows:

$$CaCo_3 + H_2O + Ca^{+2} + HCO_3^- + H^+ \text{ (soil sol'n)} + OH^- \longrightarrow H_2$$

The solution $CaCO_3$ and resultant rate of the above reaction is related directly to the rate at which the OH^- ions are removed from solution (Tisdale and Nelson, 1975).

Liming materials commonly used are the oxides, hydroxides, carbonates, and silicates of calcium, or calcium and magnesium with an accompanying anion that will reduce the activity of the hydrogen and aluminum solubility in the soil solution. These materials are calcium oxide (CaO), commonly called unslaked lime, burned lime or quicklime, calcium hydroxide $\{Ca(OH)_2\}$, called slaked lime, hydrated lime or builder's lime; and the carbonates of calcium and magnesium ($CaCO_3$) and $\{CaMg(CO_3)_2\}$. Calcide ($CaCO_3$) is called calcitic limestone and dolomite $\{CaMg(CO_3)_2\}$ is called dolomitic limestone. Marls, a soft,unconsolidated calcium carbonate, and slags, industrial by-products, as well as flyash, are also classed as liming materials.

The ability of any of these neutralizing agents to react with acid is markedly different and is referred to as its $CaCO_3$ (CCE) equivalent; the rate at which it reacts is related to particle size. Pure calcium carbonate, with a neutralzing value considered to be 100 percent, is the standard against which other liming materials are measured, as shown in Table 3.

Table 3. The neutralizing value (CCE) of the pure forms of some commonly used liming materials (Fert and Fert, 1975).

Material	Neutralizing Value (%)
CaO	179
$Ca(OH)_2$	136
$CaMg(CO_3)_2$	109
$CaCO_3$	100
$CaSiO_3$	86

The relative quantities of calcite and dolomite and particle size are the two most important factors affecting reaction rate. The molecular weight of calcium carbonate is 100; it is 84 for dolomite. Since one mole of each of these substances will neutralize two molecules of acid, 85g of magnesium carbonate will neutralize the same amount of acid as 100g of calcium carbonate. Therefore, magnesium carbonate will neutralize 1.19 times as much acid as the same weight of calcium carbonate.

Cost, the rate at which a product arrests acidity and its projected effective potential within the soil must be considered when selecting a liming material for extremely acid soils.

Dolomitic limestone generally reacts more slowly within the soil than does calcitic limestone. Research has indicated that when uniformly mixed with soil, calcitic limestone disappears at a rate approximately twice that of dolomitic limestone (Barber, 1967). As a result, it may be practicable to use dolomitic limestone in a deeply plowed furrow to react over a longer period of time where additional applications are not feasible. Surface soils could be treated with a faster-acting liming agent like calcite, even though it has a lesser $CaCO_3$ equivalency, for quicker vegetation response. Unlike subsoil applications, it is easier to apply additional

lime to the soil surface.

Barber recommends the utilization of limestone fine enough for at least 80 percent to pass through a U.S. Standard No. 8 sieve. This assures an adequate surface area on the limestone particle for chemical effectiveness; it may also add to its cost.

Limestone can be applied to the surface, surface and subsoil, or be split into two applications within the plow layer. Liming of subsoils has generally had no effect on subsequent plant yields (Barber, 1967). Hourigan et al. (1961) has found that subsoil liming has little effect on yield when surface soil is adequately limed. Longnecker and Merdle (1952) reported that root extension into acid soil was limited but maximum yields were obtained by surface liming only. Woodhouse (1956) compared surface, mixed and plow-sole applications of lime to a clay loam soil. Maximum yields were obtained from mixed application followed by the plow-sole application. Surface liming yielded little additional growth compared to soil that was unlimed. Recommended application procedures will vary.

In situations where toxic metal migration is dangerous and soil covers are used of sufficient depth to suppress upward movement into the root zone, subsoil liming should be practiced prior to topsoiling. In this manner, heavy metal solubility as well as movement can be suppressed because of an increase in pH and a subsequent immobilization of metals.

Flyash can be an effective means of lowering soil pH by increasing the activity of the Ca^{++} and OH^- ions. Flyash usually contains higher concentrations of essential plant nutrients, excluding nitrogen, than most cropland soils. Recommended application is 70 metric tons/acre with a pH of 4.5 - 5.0 and 335 - 1790 metric tons with a pH of 2.0 - 3.5. Application of flyash would also meet one of the underlying requirements of the

AML program; utilization of an area's resources (Adriano et al., 1980).

Besides supplying nutrients to the soil, flyash can also aid in soil moisture-holding capacity. It is not effective in holding water by itself, but when mixed in soil at eight percent by weight, water-holding capacity is significantly increased, although plant available water is not significantly raised. This additional water is held at tensions greater than most plant's ability to extract water. This added moisture may be an aid to dissolution rates if flyash is used in conjunction with limestone.

Flyash must be used with caution, as it may lower pH, particularly when produced from high sulphur coals. Eastern coal is characteristically high in sulphur; western lignite and subbituminous coals are low in sulphur and characteristically low in pH. Accumulations of boron, molybdenum, selenium and soluble salts (notably calcium and magnesium) from flyash are the most serious constraints in this area.

Dry matter yield increases associated with flyash application to soil have been attributed to correction of micro-macronutrient deficiencies. Used with limestone, it can have a valuable contribution to soil tilth. But any utilization of ash should only follow a thorough laboratory analysis for any toxic substances in the ash and a good understanding of its neutralizing ability.

Knabe (1959) found that flyash can be used in areas where toxic and water-repellent spoils are dominant. Lime is recommended in those areas exhibiting low toxicity and normal infiltration.

The use of fertilizer and/or fertilization amendments is required because of the low nutrient content in the buried acid soils and the unavailability of some nutrients.

Lack of nitrogen is the chief reason for vegetative failure on coal spoils and the most difficult problem to overcome since it is needed in large amounts and is quickly leached away. Slow-release fertilizer has been developed to help overcome leaching problems, but it is extremely costly. Establishment of legumes is suggested along with any nitrogen recommendations; clover is better than fertilizer in providing nitrogen gradually and continuously. If innoculated, legumes provide adequate supplies of nitrogen, but will require fertilizer until they become established. As legumes are slow to germinate, and their germination is sensitive to solutes in fertilizer (particularly N and P lying on the soil surface), fertilization should take place three to six weeks after initial seeding.

Alternatives to commercial fertilization include sewage sludge, manure, peat and pulverized fuel ash, covered under chemical abatement (see Table 4). Sewage sludge can be an economical fertilizer. It helps the soil rebuild structure and contains a high nutrient content. Usually a slow nutrient release is associated with sewage sludge, which is important in minimizing leaching of nitrates. The high organic matter can also complex heavy metals in the subsoil and neutralize their toxicity, but it can also result in a carbon to nitrogen ratio which locks up nutrients, particularly nitrogen. This problem can be rectified by use of aged sludge with a lower C:N ratio. Probably the most important constraint associated with the use of sludge is the possible build-up of toxic metals from repeated applications, especially if the sludge originates from industrial sources.

Farmyard manure is another readily available soil amendment. Feedlots are often in search of a disposal program for their nitrate-rich manure wastes. Again, it is also a good component for enhancing soil structure, but should also be used only after aging. A high C:N ratio and possible adverse

Table 4. Organic material fertilizer sources (Bradshaw, 1980).

Material	Composition (%) N	P	K	Organic Matter	Special Problems
farmyard manure	0-6	0-1	0-5	24	can be toxic direct on plants
pig slurry	0-2	0-1	0-2	3	high water content
poultry manure (broiler)	2-3	0-9	1-6	68	high levels of ammonia
poultry manure (battery)	1-5	0-5	0-6	34	high levels of ammonia
sewage sludge (air dried)	2-0	0-3	0-2	45	possible toxic metals and can have high water content
peat (partly dried)	0-1	0-005	0-002	50	variable, especially calcium content
mushroom compost (dried)	2-8	0-2	0-8	95	none except high lime content
pulverized fuel ash	0	0-05	2-2	0	high boron

effects from nitrates, uric acid and ammonia compounds in fresh manure can occur.

Poultry manure is twice as rich in nitrogen as most farmyard manures and is always dry, resulting in ease of handling and application. As with any manure, it should be incorporated into the soil to insure that uric acids and ammonia compounds don't burn plant tissue.

Peat moss, found in Montana, is excellent for increasing soil water-holding capacity and can be a good source of nutrients.

From soil samples analyzed as a part of this study the following recommendations for liming and fertilization were made:

Soils with a pH level of four or less should be treated with a 20 ton/acre minimum of lime for every foot of soil. With conditions that range

from pH levels of five to six, a lime treatment of 10-ton/acre/foot of soil may be adequate. For soils above pH six, lime will not be required. The lime should be applied to the spoils before topsoiling and incorporated by disking. If the native soils used for covering are of a pH six or less, then an application of lime to the cover soil must also be applied.

The 20 ton recommendation may be required at the sites with a pH of five to six as an aluminum toxicity problem may exist. At the 20 ton/acre rate the lime can precipitate the Al^{+++} out of solution and thus alternate its toxicity. At approximately eight ppm, root development problems begin and an increase of aluminum in the piles may result.

Unfortunately, lime ties up the availability of phosphorus to plants; an application of P_2O_5 at rates of 300 lbs/acre or more will probably be required. This is particularly important for the establishment of legumes. They may germinate and respond well the first year but, because of the liming, growth decreases in the following season.

In addition, the desorption requirement for phosphorous in the clay interlayer must be satisfied before phosphorous is available for plant utilization.

Even without specific fertilizer recommendations, the spoils and cover soils should be limed, if necessary. As long as the soil is wet the lime will precipitate the phosphorous out of solution. This is important because available phosphorous cannot be determined if lime is not allowed to react due to dry conditions. Therefore, irrigation may be required after liming. A period of at least one month must follow to allow the lime to come into equilibrium with the soil. After this period, samples should be taken and submitted for fertilizer recommendation.

f. Coulee channelization

Channeling or diverting runoff around a gob pile could eliminate a portion of the water from turning acid; however, the majority of the acid drainage that occurs originates from water that drains through the pile and then runs from beneath it and above the buried soil. A sudden spring storm or a heavy snowfall followed by a rapid snowmelt would probably damage the diversion canal, rendering the reclamation effort useless. A property owner from the Sand Coulee area tried channeling acid water through a wheatfield in Number Five Coulee, but spring rain runoff of 1980 buried the ditch banks and continued to spread acid water throughout the field.

Diversion canals would require yearly maintenance and would only partially solve the acid problem.

g. Land management alternatives

If the contention is correct that excess groundwater associated with acid mine discharge is locally derived, then land management changes can be adopted that will serve as abatement techniques. Alternative cropping sequences, alternative crops, and mechanical practices can be employed on recharge areas to reduce the percolation of excess water below the root zone.

Continuous or flexible cropping sequences can be substituted for the fallow method, which conserves soil moisture on an annual basis. Farming more intensively allows for a more efficient use of soil moisture based on current conditions; it also results in the growth of more crops per acre and the reduction of fuel bills per unit of crop.

Alternate crops can be selected that will: dry out deeper subsoils, control

plant diseases and weeds, maintain soil organic matter and improve tilth. Deep-rooted species and native grasses are efficient users of moisture that restrict the vertical percolation of water. These types of crops can be used as alternatives to cereal grains which use fewer inches of soil water; if grown continuously, they can replace the current small grain fallow system which may be contributing to the pollution of underground water.

Mechanical practices which work to reduce the infiltration of excess moisture can be implemented in areas disturbed by acid mine discharge. Grass waterways, dikes and terraces can be established at recharge sites where ponded water collects. Tile drains can be placed to intercept water before it can become acidified. Observation wells can be located to monitor watertable fluctuations as an adjunct to determining whether to crop or not.

The usefulness of more intensive farming methods as an abatement technique remain to be substantiated through research; there appears to be a correlation between acid mine discharge and saline seep. Considerations which appear in the matrix are derived in part from past conclusions drawn from saline seep research and similar conclusions developed in acid discharge investigations.

A slim possibility exists that further coal mining may occur in the Belt and Sand Coulee areas. Resource 89, a Montana Power Company electrical generating project, has been proposed for Great Falls, Montana. A MPC representative (Ed Handle, pers. comm.) stated that no commercial coal mines now exist in the area to support Resource 89. The company is soliciting bids from throughout the state of Montana. The bid will be awarded in accordance with prevailing market prices for coal, quality of

the coal, cost required by state and federal laws to insure clean air and water, and cost of transportation. When compared to these criteria, the unmined coal in the Belt and Sand Coulee areas has several inherent disadvantages: there is no existing development, the sulpher content is higher in this coal than in eastern Montana, and the coal is not uniform in quality. In addition to the costs of bringing an operation on line, these inherent problems may cause local mining to be too expensive.

h. Revegetation

Species selection for revegetation in the Belt-Sand Coulee area is based on vegetation and soil inventory studies as well as commercial seed availability. Dominant species identified during the baseline study comprised an initial list of species to be used for revegetation purposes. Where some species are not commercially available, other species have been chosen which reflect adaptability to expected site conditions, given soil and climatic considerations. Validity of species selection may be judged by establishment potential and post-reclamation land use management. Selected species are included in Table 5.

Four community types were identified during the baseline vegetation inventory. Two of these types (skunkbush sumac/bluebunch wheatgrass and mixed grassland) are found on well-drained soils of upper hillsides. The remaining two types (mixed shrub/Kentucky bluegrass and western snowberry/Kentucky bluegrass) occupy lower slopes having clay-derived soils. Climax vegetation has developed in response to differences in soil/moisture relationships at these sites.

Two seeding mixtures (presented in Tables 6 and 7) have been developed that reflect both dry and moist site conditions. Drought-tolerant species

Table 5. Selected species for revegetation, Belt-Sand Coulee area, Montana, 1981.

	Species
AGDA	Agropyron dasystachyum
AGIN	Agropyron inerme
AGSM	Agropyron smithii
AGTR	Agropyron trachycaulum
BOGR	Bouteloua gracilis
BRIN	Bromus inermis
CRDO	Crataegus douglasii
ORHY	Oryzopsis hymenoides
PHPR	Phleum pratense
PRVI	Prunus virginiana
POPR	Poa pratensis
STCO	Stipa comata
STVI	Stipa viridula
ACMI	Achillea millefolium
ASCI	Astragalus cicer
BASA	Balsamorhiza sagittata
LIPE	Linum perenne
LUPSPP	Lupinus spp.
MESA	Medicago sativa
RACO	Ratibida columnifera
RHTR	Rhus trilobata
RISE	Ribes setosum
ROAR	Rosa arkansana
SYOC	Symphoricarpos occidentalis

are included in the mixture for dry sites; those species best suited to more mesic conditions comprise the mixture for moist sites. Shrub and tree transplant stocking rates are also based on inventory coverage estimates. Post-land use management will be directed towards livestock grazing; the selection of forage species reflects this choice.

Table 6. Seed mixture and stocking rates, dry site community, Belt-Sand Coulee area, Montana.

Revegetation components:

A. Seed mixture

Species	Lbs. seed/acre Broadcast	Lbs. seed/acre Drill	Lbs. planting material/acre Broadcast	Lbs. planting material/acre Drill	PLS/ft^2
AGIN	8	7	9	8	18
BOGR	2	1	6	3	6
STCO	4	2	17	8	1
ORHY	1	1	1	1	3
AGDA	6.5	5.5	9	7	17
AGTR	5	2	6	3	10
ACMI	.25	.25	.5	.5	21
PEPU	.25	.25	.5	.5	2
LIPE	.25	.25	.5	.5	3
BASA	.50	.50	1	1	1
RACO	.25	.25	1	1	1
ASCI	2	2	2	2	6
TOTAL	30	22	53.5	35.5	89

B. Seedlings

Species	Stocking Rate
PRVI	15
RHTR	80
ROAR	65
SYOC	15
	175 trees per acre

Table 7. Seed mixture and stocking rates, moist site community, Belt-Sand Coulee area, Montana.

Revegetation components:

A. Seed mixture

Species	Lbs. seed/acre Broadcast	Lbs. seed/acre Drill	Lbs. planting material/acre Broadcast	Lbs. planting material/acre Drill	PLS/ft^2
AGSM	6	4	9	6	7
POPR	1	1	1.5	1.5	22
STVI	6	4	8	6	13
AGIN	3	2	3	2	4
BRIN	1	1	1	1	2
PHPR	1	1	1	1	23
AGDA	6	4	8	5	12
AGTR	4	3	5	4	10
ACMI	.25	.25	.5	.5	21
ASCI	.50	.50	.5	.5	1
LUPSPP	.25	.25	.5	.5	1
MESA	1	1	1	1	4
TOTAL	30	22	39	29	120

B. Seedlings

Species	Stocking Rate
CRDO	55
PRVI	50
RHTR	15
RISE	70
ROAR	90
SYOC	45
	325 trees per acre

Drill seeding rates are based on 22 pounds per acre; broadcast seeding rates have been proportionately increased to 30 pounds per acre. The more highly competitive "tame" species (i.e., timothy, Kentucky bluegrass, smooth brome, etc.), are seeded at lower rates to encourage establishment of native species. Mixtures and rates may be modified to reflect species adaptability to post-reclamation ecological conditions, modifications in land use goals or commercial availability. It should be stressed that only seed having the highest purity and germination rates should be utilized. Seed should be chosen from 1) stands regionally proximal to the project area, or 2) areas having climatic conditions which closely parallel the Belt-Sand Coulee area.

Legume seed should be inoculated with the proper rhyzobium prior to delivery. Inoculation helps to ensure the increased adsorption of nutrients, reduce internal plant resistance to water flow and improve water uptake. Grass seed should receive proper stratification or scarification prior to its delivery. Potential seed material sources are listed in Table 8. Preferred varieties and/or certified seed should always be used.

Following shaping and fertilizer application, the soil surface can be disked and/or harrowed along the contour. Disking breaks up large clods which interfere with seeding, while harrowing acts to smooth and compact the seedbed to make it more amenable to drill seeding.

Planting should immediately follow seedbed preparation. Seed may be broadcast on deep, loose seedbeds. Hand broadcasting using a manually operated cyclone-type bucket spreader is the most practical method of application on relatively small or inaccessible sites. Mulch should always be used to cover and protect seed broadcast onto the soil surface. A mechanical blower can be used to broadcast seed on larger, more readily accessible sites.

Table 8. Potential seed material sources, Belt-Sand Coulee area, Montana 1981.

Adsit Farm and Ranch Services
Decker, MT. 59025
(406) 757-2234
State certified seed grower

Big Sky Wholesale Seeds, Inc.
Shelby, MT. 59474
(406) 434-5011
Wholesale seed

Bitterroot Nursery
521 N.E. Eastside Hwy.
Corvallis, MT. 59828
(406) 961-3806
Nursery

Cenex Seed Company
H.C. Johnson, Mgr.
P.O. Box 1748
Billings, MT. 59103
(406) 656-7150
Wholesale seeds

Clear Creek Hereford Ranch, Inc.
Box 595
Chinook, MT. 59523
(406) 357-4207
Seed grower

Boyd Crawford
Box 354
Fort Benton, MT. 59442
(406) 622-5327
Individual collector

DeKalb
3821 First Avenue South
Billings, MT. 59101
(406) 252-3715
Wholesale seeds

Lawyer Nursery, Inc.
Route 2, Box 95
Plains, MT. 59859
(406) 826-3229
Nursery

Lund Seed Co., Inc.
Box 68
Big Sandy, MT. 59520
Individual collector

Marchie's Nursery
1845 South Third West
Missoula, MT. 59801
(406) 542-2544
Nursery, collector

Northrup King Co.
P.O. Box 398
Billings, MT. 59103
(406) 252-0568
Wholesale seed

Bill Skorupa
Box 136
Bridger, MT. 59104
(406) 662-3358
Seed grower

Conventional (one-pass) drilling on the contour is a more useful technique on slopes of 3:1 or flatter, which have a well-prepared seedbed. Advantages of drilling include: 1) the placement of seed at the most appropriate depth to enhance germination, and 2) the more even distribution of seed.

Seed drills should be equipped with seed compartments, a seedbox agitator, a seed-metering device, furrow openers and packer wheels. Drill calibrations

can be made using available tables to obtain the desired rate of application of Pure Live Seed (PLS) per foot for various row spacings and species. An easier method of calibrating the drill involves first, mixing the seed in proper proportions and then, adjusting the drill for the correct number of seeds per foot using an easily recognizable species. All other seeds in the mixture will then be in the desired proportion.

Spring seeding dates are usually April 15 to May 15; fall seeding generally commences October 15 until weather becomes prohibitive. Planting seasons may be modified to meet local conditions.

Hydroseeding involves the pneumatic application of fertilizer, seed and mulch in a water slurry onto a prepared seedbed. It is a procedure not ordinarily used for rangeland seedings due to high cost. Hydroseeding is, however, recommended for slopes of 3:1 or greater where farm equipment cannot be operated.

Although first-year irrigation is desirable for species establishment, it is not recommended for this area; the cost of providing water to the sites cannot be justified owing to the disjunct distribution of relatively small areas of disturbance.

Seedings should be inspected periodically after planting. If seed fails to germinate or seedlings fail to emerge, early recognition of the reasons for failure allows for reseeding and salvage of a portion of the seedbed preparation expense. Examination of establishment success factors includes seedling abundance, uniformity of distribution over the soil surface and presence of undesirables. Seedlings should be observed over a period of one to two years to properly assess establishment success. Stand establishment can be quantitatively measured by evaluation of plant frequency

as outlined in the Interagency Forage, Conservation and Wildlife Handbook (1973).

During the period of establishment and into the second to third season of growth, livestock grazing should be deferred. Grazing readiness can be determined by depth of rooting and plant vigor. A long-lasting productive seeding with sustained plant health and vigor can be enhanced by grazing at recommended stocking rates and appropriate seasons. Conservative stocking results in sustained high yields of vegetation and high animal productivity. It may be necessary to temporarily fence reclaimed sites from adjoining pastures and range to reduce the risk of premature grazing by livestock.

i. No action

The abatement technique described as "no action" is precisely that; it will apply in those instances where property owners are either 1) disinterested or 2) opposed to the reclamation of abandoned mine sites.

Support for the "no action" option is evidenced in T.A.P., Inc.'s survey results (1980): 97 percent of the respondents in Belt indicated they were either better off or about the same as others in rural Cascade County; 87 percent of those questioned in the Sand Coulee area responded in a similar fashion. A substantially high number of survey participants in both localities indicated that none of their property had been affected by any pollution from abandoned mines and that they had suffered no economic loss from any type of pollution relative to those mines. In cases such as these, the costs of reclamation may not be justified by the level of property owner interest.

Certain area residents view the abandoned mine sites as historic landmarks which add local "color" to the communities. They would like the gob piles

and adits to remain as they are. The personal preference of each property owner would, of course, be given top priority over all other abatement options in these circumstances.

A concern widely expressed by local residents is that they will ultimately be supporting the cost of reclamation projects with their own money, in the form of taxation. This resistance to spending tax dollars for these types of projects is exemplified by the repeated contention that funding should come from the private sector. The rationale for "no action" in this case is that the people to be affected will not condone the source of funding.

3. Considersations

Considerations to each abatement technique exist which aid in selecting the most appropriate alternative for each site. These appear in Matrix 2.

a. Reclamation costs

Cost estimates have been developed for each abatement technique (see Table 9). The estimating procedure involves dividing each technique into two categories: 1) Earthwork and 2) Revegetation. Consideration is given to finite units such as material volumes, acreages, equipment utilization time and labor requirements. The cost for these units has been obtained from manufacturers, suppliers, contractors and the Montana Department of Highways tabulation of low bid prices and computation of average prices, January 1981 - June 1981. Two total costs appear for each abatement technique: cost/cubic yard and cost/acre. A ten percent maintenance and monitoring figure has been added to the total cost in each category.

Cost determinations are dependent on specific site parameters such as topography, soils, vegetation, geology, hydrology, etc. A site-specific

TABLE 9
ITEMIZED COST ESTIMATES BY ABATEMENT TECHNIQUE

ABATEMENT TECHNIQUE	EARTHWORK: Pneumatic Backfill	Excavation	Excavation-Borrow	a Haul	Topsoil Salvage and Replacement	Topsoil	Backhoe	b Liners	Maintenance	Total Cost / cu. yd.	REVEGETATION: c Seedbed Preporotion	d Seed	e Seeding	f Fertilization	g Liming	h Mulch	i Fencing	Maintenance	Total Cost / acre	Remarks
COST/ITEM	$15.00/cu.yd.	$3.00/cu.yd.	$6.07/cu.yd.	$.15/mi.yd. ($3.75)	$1.37/cu.yd.	$8.00/cu.yd.	$6.00/cu.yd.	$65.00/cu.yd.	add 10%		$75.00/acre	$235.00/ocre	$140.00/ocre	$175.00/ocre	$2400.00/ocre	$336.50/acre	$900.00/acre	add 10%		
Pneumatic Injection	X			X					1.88	20.63	X	X	X	X	X	X	X	426	4688	
Alternative Use Of Material Waste				X				X	6.88	75.63	X	X	X	X	X	X	X	426	4688	Return on sale est. $4.00/cu.yd.
On-site Waste Burial		X	X	X	X	X		X	8.72	95.91	X	X	X	X	X	X	X	426	4688	
Off-site Waste Burial		X	X	X	X	X		X	8.72	95.91	X	X	X	X	X	X	X	426	4688	
Chemical Abatement and Fertilization			X	X	X	X			1.92	21.11	X	X	X	X	X	X	X	426	4688	Liming ond fertilization to occur at all sites: cotegory implies no eorthwork.
Caulee Channelization							X		.60	6.60		X	X	X		X	X	179	1965	Costs vory widely with terrain.
Land Management Alternatives																				
• Intensive Farming																				Exact costs nat available; ossume benefit from AMD abatement.
• Future Mining																				Exact casts not ovoilable.
Revegetation											X	X	X	X		X	X	186	2048	Assume no grading or related costs.
No Action																				No costs.

a Assume a 25 mile haul. Haul costs are $.15/mi.yd., ar $.15 ta haul one cubic yard of material one mile.

b Based an bentanite at $65.00/cu.yd.

c Per acre cast bosed on a $23.38/hr. rate.

d Assume overage cost af moist and dry-site mixes for bath drill ond broadcast techniques.

e Assume overoge 26 lbs./ocre.

f Rates subject ta site-specific soil tests. Assume average 175 lbs./acre.

g Assume overoge opplicotion rote af 15 tans/acre.

h Assume application rate of 2000 lbs./acre.

i Includes materiol casts and labor.

range of reclamation costs by abatement technique appears in Matrix 3. All estimated costs are time-dependent and should be compared on a similar time basis.

Recommended abatement techniques are prioritized in Matrix 3. In most cases, on or off-site pneumatic injection has been offered as a top priority. Costs appear only for the first priority option.

b. Predicted success

The success of each reclamation effort should be regarded in terms of predetermined objectives. For example, if an adit and gob pile are located in an area that is surrounded with range, then the most desirable goal would be to return the affected area to range. The same results should be considered for cropland and residential areas.

The symbols of success criteria and definitions are given below for each predicted success rating:

- \+ Complete success - Total elimination of the problem without future maintenance problems or monitoring techniques five years after reclamation begins.

- ⊕ Moderate success - Total elimination of the problem with maintenance monitoring techniques required less than once every three years with a possibility of complete success

- 0 Fair success - Total elimination of the problem with maintenance and monitoring techniques required at least once every three years but no more than annually. Complete success is doubtful without major reclamation modification.

- \- Poor success - Problems exist which require constant to more than yearly maintenance and monitoring of the existing reclamation proposal. Complete success is doubtful without a change of reclamation plan.

c. Local popularity

Local reaction to the undertaking of abatement technqiues can only be

evaluated from opinions expressed before any abatement procedure has occurred. Residents in the Belt and Sand Coulee areas have demonstrated, through their response to a questionnaire and in private conversations, some preconceived notions about the anticipated results of certain abatement techniques. Local popularity of an abatement technique can best be assessed through the dissemination of information and at public meetings. The reaction to each abatement technique has been subjectively rated as locally popular (+), neutral (0), or locally unpopular (-).

It is too early to judge the reaction to recent pneumatic backfilling procedures conducted in these areas. Many residents have expressed apprehension about mine plugging procedures in general; several cite the deterioration of local water supplies as a result of "underground rechannelling" due to previous attempts to plug mines.

The use of material waste for fill and commercial products is a locally popular abatement technique. Most residents feel that this is a practical method of utilizing a commodity for which a small market exists.

No reaction has been elicited to the burying of waste on or off-site, or to the use of chemical abatement and fertilization.

There has been little reaction to the method of coulee channelization; some individuals have suggested it as a positive solution while others have condemned it as causing the problem to emerge elsewhere.

Land management changes in the form of alternative agricultural practices are generally gaining widespread acceptance regionally. Many local operators have expressed the desire to start farming more intensively.

It is difficult to assess the local reaction of further coal mining in the area. Certain respondents feel there is an economic incentive for the community to resume mineral extraction; there are others who would resist all efforts at future mining.

It is an apparently unanimous opinion that the revegetation of disturbed areas is an aesthetically and otherwise appealing abatement technique.

Most residents have expressed a desire to see some kind of abatement measure taken to rectify the appearance and negative impacts of abandoned mine sites (except for certain sites, considered to be local landmarks).

d. Benefits

The benefits to be realized from reclamation include: aesthetic improvement, residential and agricultural real estate value improvement, increased revenue from crops and livestock and reduced risk to personal health and safety. In a short-term sense, the reclamation process itself could supply jobs for local laborers.

T.A.P., Inc. has estimated that in terms of present value, $1,771,290 worth of positive financial benefits could accrue to the Belt and Sand Coulee areas combined with a broad reclamation improvement plan.

The benefits to be achieved through reclamation are difficult to quantify; they are predicated on the success of the reclamation effort itself. For the purposes of this matrix, it has been assumed that the benefits to be derived from each abatement technique are positive (+).

e. Future maintenance and monitoring

Maintenance performed on the site after initial reclamation is completed

vary from an occasional on-site observation to a complete site renovation. Maintenance tasks require time and money and should be included in the cost estimate of the alternative reclamation procedure. The following rating scheme is found in the matrix:

+ - Low to nonexistent - A minimum amount of maintenance for establishing vegetation or for checking and repairing a seal up to five years. After five years no maintenance should be required.

⊕ - Minimal - A minimum amount of maintenance for establishing vegetation or for checking and repairing a seal. Minor modifications to the original reclamation plan may be necessary to insure success. Complete success may take longer than five years.

0 - Moderate - Maintenance required yearly and on a routine basis to insure that waste pile contamination is not spreading and that the desired vegetation is producing at a desirable rate. Complete reclamation success is probably not possible under this reclamation plan.

\- - Major maintenance problems - Maintenance is required yearly and on a routine basis to insure that waste pile contamination is not increasing. Following intense fertilization and chemical abatement, vegetation will germinate and exist on a yearly basis. The reclamation process is reviewed each year.

f. Hazards

The primary reason for allocating funds to abate negative impacts of abandoned mines is to eliminate existing health and safety hazards and improve aesthetics. Since abandonment, derelict mines and ancillary structures have become decrepit and unsound due to a lack of maintenance. Subsidence is evidenced frequently along old adit shafts and associated wooden structures are decayed and collapsing. Spoil piles, in combination with acid drainage of mines, kills vegetation downhill and produces areas of severe erosion. The destruction caused by the acid water spreads yearly as drainage patterns change and chemical buffering agents in the soil are

diminished. Groundwater can also be affected by the acid water which creates a health hazard for those whose water is supplied by wells.

Each hazard is considered and rated separately on the matrix. The rating criteria and definitions are given below for each hazard:

1. Safety

   + Low to nonexistent - The mine portals are sealed and the potential for subsidence has been eliminated.

   0 Minimal - The mine portals are sealed but the potential exists for subsidence.

   - Severe - Mine portals are left open and the potential for subsidence exists.

2. Health

   + Low to nonexistent - Complete elimination of the acid water discharging from the adits and draining from the spoil piles.

   ⊕ Minimal - Complete elimination of the acid water discharging from the adits, but acid water draining from spoil piles remains a problem.

   0 Moderate - Acid water discharge remains a problem, but acid water drainage from the spoil piles has been eliminated.

   - Severe - Acid water discharge remains a problem and so does acid water drainage from spoil piles.

3. Environment

   + Low to nonexistent - Vegetation has returned to the barren areas where spoil piles and acid water discharge existed and the potential for further acid discharge and drainage has been eliminated.

   0 Moderate - Vegetation has returned to the barren areas occupied by adits and spoil piles not producing acid water discharge.

   - Severe - The areas occupied by the spoil piles and the acid water discharging portals remain barren and are spreading.

g. Downhill movement

Potential downhill movement exists whenever a soil disturbance occurs on an incline. The degree of downhill movement depends on the soil texture, amount of precipitation, wind speed, area disturbed, slope, and vegetative or amendment cover. All of these factors must be taken under consideration when a prediction is made which concerns soil movement.

- \+ Maximum soil stability - Vegetation is established and soil stability is realized within five years. Less than two tons of soil per acre per year is lost or moved downhill.
- 0 Moderate soil stability - Vegetation and soil stability can be realized but may take more than five years. Between two and five tons of soil are moved per acre per year.
- \- Low to nonexistent - Vegetation and soil stability are not likely for a number of years over five years and soil movement rates are consistently over five tons per acre per year.

4. Site specific recommendations

Four matrices are presented which:

(1) describe physical site-specific characteristics;

(2) define nine abatement techniques and their considerations;

(3) rank abatement techniques on a site-by-site basis, by cost;

(4) present specific reclamation components by site.

The matrices provide a rapid assessment of techniques and considerations; legends contain rating categories which define limiting criteria by symbol.

Pneumatic injection is generally shown as the primary means of eliminating spoil piles. If a portal is not present near a spoil pile or if the portal is actively discharging water, piles should be hauled elsewhere to an open adit that provides sufficient space to accept additional coal slag. Coal slag should also be injected at those locations where a caved-in portal could easily be re-opened specifically for pneumatic injection.

MATRIX 1-A

SITE DESIGNATION		Portal Present	Acid Mine Discharge Present	Percent Slope	Soil Type	Vegetation Type	Current Land Use Management	Waste Pile Type	Structure Present	Access	Remarks
7-1	Antelope Creek	No	No	16	179F	2	2	1	No	—	
7-2	Antelope Creek Subsidence	No	No	16	179F	2	2	1	No	—	
7-5	Belt A	Yes	Yes	59	46F	1	2	2	No	+	
7-6	B&M Coulee	Yes	No	44	179F	3	2	1	No	+	Flow from portal est. 1gpm
7-7	Centerville A	*	No	47	46F	1	2	1	No	+	Adit caved
7-8	Brown	Yes	No	50	46F	1	2	1	Yes	+	
7-9	Centerville B	No	No	47	46F	1	2	1	No	+	Flow from portal est. 1-2 gpm pulverized overburden material
7-10	Centerville C	Yes	No	47	46F	3	2	"1	No	—	Adit caved "pulverized overburden material
7-11	Centerville D	No	No	47	46F	1	2	1	Yes	—	
7-12	Centerville E	Yes	No	50	46F	1	2	1	Yes	+	Access poor to drainage, slopes very steep
7-13	Centerville F	*	No	65	179F	3	2	1	Yes	+	
7-14	Centerville G	Yes	No	65	179F	3	2	1	Yes	+	
7-16	Centerville Mobile Homes	Yes	No	46	179F	4	2	1	No	+	
7-17	Cottonwood Seeps	Yes	No	32	46F	3	2	1	"No	—	"boiler tank present
7-19	East Belt Mine	Yes	No	19	179F	4	2	1	Yes	+	
7-20	Giffen	Yes	Yes	25	179F	2	2	1	Yes	+	
7-24	Lewis Coulee	Yes	Yes	75	46F	1	2	1	No	+	
7-26	North Belt Mine	Yes	No	44	46F	3	2	1	Yes	—	
7-27	N. End, NW Slope, Sand Coulee	No	No	41	43F	3	2	1	No	—	
7-28	Number Five Coulee	Yes	No	16	179F	4	2	1	No	+	Portal present E. side of road; damage to cropland evident
7-29	Number Five Coulee Mouth	Yes	No	16	179F	4	2	1	Yes	+	Access limited for southernmost waste pile

Portal Present
- * - unknown

Soil Type
- 179F - Bitton-Roy Complex
- 46F - Big Timber - Costner Complex
- 43F - Yawdin Rock Outcrop
- 49C - Darrot-Costner Complex

Vegetation Type
- 1 - skunkbush sumac / bluebunch wheatgrass
- 2 - mixed grassland
- 3 - mixed shrub / Kentucky bluegrass
- 4 - snowberry/Kentucky bluegrass

Current Land Use Management
- 1 - agricultural crop
- 2 - unimproved range
- 3 - residential

Waste Pile Type
- 1 - coal slag
- 2 - cinder

Access
- + - good
- — - poor

MATRIX I-B

SITE DESIGNATION		Portal Present	Acid Mine Discharge Present	Percent Slope	Soil Type	Vegetation Type	Current Land Use Management	Waste Pile Type	Structure Present	Access	Remarks
7-32	Sand Coulee Midtown	*	Yes	20	179F	4	3	1	No	+	
7-33	Sand Coulee North	Yes	No	20	179F	1	2	1	No	+	
7-34	Belt SE	Yes	Yes	75	46F	1	2	1	No	+	
7-36	Stockett NE	No	No	50	46F	2	2	2	No	+	
7-37	Stockett SE	No	No	20	179F	2	2	1	No	+	Vegetation sparse where seeps are present
7-38	Stockett West Ridge	Yes	No	34	179F	2	2	1	No	+	
7-39	Subsidence NW Centerville	Yes	No	20	179F	3	2	1	No	+	Portal partially caved
7-40	Tracy	Yes	Yes	46	179F	4	3	1	No	+	
7-41	Tracy NE, A	Yes	Yes	26	179F	2	1	1	No	−	
7-42	Tracy NE, B	*	Yes	26	179F	2	1	1	No	−	
7-43	Tracy South	*	No	50	179F	1	2	1	No	+	
7-44	Tracy SW	Yes	No	20	179F	3	2	1	Yes	+	
7-45	Upper Cottonwood A	No	No	25	49C	4	2	1	No	+	Adit caved
7-46	Upper Cottonwood B	Yes	No	32	179F	3	2	1	Yes	+	
7-47	Upper Cottonwood C	Yes	Yes	32	179F	3	2	1	No	−	
7-48	Upper Sand Coulee A	Yes	Yes	41	179F	3	3	1	No	+	
7-49	Upper Sand Coulee B	*	Yes	41	179F	3	2	1	No	+	Subsidence present
7-50	Western	Yes	No	20	179F	4	2	1	Yes	+	Five mine cars present below waste pile
7-51	French Coulee	No	No	5	179F	4	2	1	No	+	

Portal Present
* -unknown

Soil Type
179F - Bittan-Roy Complex
46F - BigTimber-Castner Complex
43F - Yawdin Rock Outcrap
49C - Darrat-Castner Complex

Vegetation Type
1 - skunkbush sumac / blusbunch wheatgrass
2 - mixed grassland
3 - mixed shrub / Kentucky bluegrass
4 - snawberry/Kentucky bluegrass

Current Land Use Management
1 - agricultural crap
2 - unimpraved range
3 - residential

Waste Pile Type
1 - caal slag
2 - cinder

Access
+ - gaad
− - poor

MATRIX 2

ABATEMENT TECHNIQUES	Predicted Success	Local Popularity	Benefits	Future Maintenance	Hazards: Safety	Hazards: Health	Hazards: Environment	Downhill Movement
	CONSIDERATIONS							
Pneumatic Injection	+	+	+	+	+	+	+	+
Alternative use of Material Waste	⊕	+	+	+	o	⊕	⊕	+
On-site Waste Burial	o	o	+	−	o	−	o	o
Off-site Waste Burial	o	o	+	o	o	⊕	o	+
Chemical Abatement and Fertilization	−	o	+	−	o	−	−	−
Coulee Channelization	−	−	+	−	o	−	−	−
Land Management Alternatives								
• Intensive Farming	o	+	+	−	+	+	+	+
• Future Mining	o	o	+	−	−	−	−	−
Revegetation	+	+	+	⊕	+	+	+	+
No Action	+	o	+	+	−	−	−	−

Predicted Success
- \+ - complete success
- ⊕ - moderate success
- o - foir success
- − - poor success

Local Popularity
- \+ - populor
- o - neutrol
- − - unpopular

Benefits
- \+ - positive

Future Maintenonce
- \+ - low to nonexistant
- ⊕ - minimol
- o - moderote
- − - mojor problem

Hozords
- \+ - low to nonexistont
- ⊕ - minimal
- o - moderate
- − - severe

Downhill Movement
- \+ - maximum soil stability
- o - moderote soil stobility
- − - low stability

MATRIX 3-A
SITE-SPECIFIC ABATEMENT RECOMMENDATIONS AND COSTS

SITE DESIGNATION		Pneumatic Injection on-site / off-site	Alternative Use Of Material Waste	On-site Waste Burial	Off-site Waste Burial	Chemical Abatement and Fertilization	Coulee Channelization	Intensive Farming	Future Mining	Revegetation	No Action	Waste Volume	Cost / Cubic yard	Disturbance Size	Cost/Acre	Total Cost Priority I	Remarks
7-1	Antelope Creek	/ 1		3	2	X				X		500	20.63	1.0	4688	15,000	
7-2	Antelope Creek Subsidence	/				X				X		-500	17.82	1.0	4688	14,000	Costs reflect excavation, houl and topsoil to fill depressions
7-5	Belt A	/ 2	1			X		3		X		–	–	–	–	–	
7-6	B & M Coulee	1 /			2	X				X		250	20.63	.5	4688	7500	
7-7	Centerville A	/ 1		3	2	X				X		4900	20.63	2.5	4688	113,000	
7-8	Brown	1 /			2	X				X		16,000	20.63	6.0	4688	360,000	
7-9	Centerville B	/ 1		3	2	X				X		16,200	20.63	3.0	4688	348,000	
7-10	Centerville C	1 /		3	2	X				X		400	20.63	.5	4688	11,000	
7-11	Centerville D	/ 1			2	X				X		900	20.63	1.5	4688	26,000	
7-12	Centerville E	1 /		3	2	X				X		4200	20.63	5.5	4688	113,000	
7-13	Centerville F	1 /			2	X				X		–	–	–	–	–	Project completed
7-14	Centerville G HEAL	1 /			2	X				X		–	–	–	–	–	Project completed
7-16	Centerville Mobile Homes	1 /		3	2	X				X		2100	20.63	3.0	4688	58,000	
7-17	Cottonwood Seeps	1 /			2	X				X		1750	20.63	12.0	4688	91,000	
7-19	East Belt Mine	1 /			2	X				X		12,000	20.63	4.5	4688	270,000	
7-20	Giffen	1 /	2			X		3		X		56,500	20.63	20.0	4688	1,260,000	
7-24	Lewis Coulee	/ 1			2	X		3		X		–	–	1.5	4688	7,000	
7-26	North Belt Mine	1 /		3	2	X				X		2400	20.63	1.0	4688	55,000	
7-27	N. End, NW Slope, Sand Coulee	/ 1		3	2	X				X		2200	20.63	1.5	4688	52,000	
7-28	Number Five Coulee	1 /		3	2	X				X		21,000	20.63	8.0	4688	471,000	
7-29	Number Five Coulee Mouth	1 /			2	X				X		4000	20.63	3.5	4688	100,000	

MATRIX 3-B

SITE-SPECIFIC ABATEMENT RECOMMENDATIONS AND COSTS

SITE DESIGNATION		Pneumatic Injection on-site / off-site	Alternative Use Of Material Waste	On-site Waste Burial	Off-site Waste Burial	Chemical Abatement and Fertilization	Coulee Channelization	Intensive Farming	Future Mining	Revegetation	No Action	Waste Volume	Cost / Cubic yard	Disturbance Size	Cost/Acre	Total Cost	Remarks
7-32	Sand Coulee Midtown	/ 1		3	2	X				X		1650	20.63	.5	4688	3700	Site of SCM-11
7-33	Sand Coulee North	/ 1		3	2	X				X		2200	20.63	2.0	4688	55,000	
7-34	Belt SE	/ 1		3	2	X				X		8800	20.63	.5	4688	184,000	
7-36	Stockett NE	/ 1		3	2	X				X		27,000	20.63	5.0	4688	585,000	
7-37	Stockett SE	/ 1		3	2	X				X		27,000	20.63	18.0	4688	650,000	
7-38	Stockett West Ridge	/ 1		3	2	X				X		20,000	20.63	3.0	4688	415,000	
7-39	Subsidence NW Centerville	1 /		3	2	X				X		2000	20.63	1.0	4688	45,000	
7-40	Tracy	/ 1			2	X				X		2000	20.63	1.0	4688	46,000	
7-41	Tracy NE, A	/ 1			2	X				X		150	20.63	.5	4688	5500	
7-42	Tracy NE, B	/ 1			2	X				X		350	20.63	8.0	4688	45,000	
7-43	Tracy South	/ 1		3	2	X				X		6400	20.63	2.0	4688	142,000	
7-44	Tracy SW	1 /			2	X				X		8000	20.63	1.5	4688	172,000	
7-45	Upper Cottonwood A	/ 1		3	2	X				X		1000	20.63	.5	4688	22,500	
7-46	Upper Cottonwood B	1 /			2	X				X		3500	20.63	2.0	4688	82,000	
7-47	Upper Cottonwood C	/ 1			2	X				X		3200	20.63	4.5	4688	87,000	
7-48	Upper Sand Coulee A	/				X				X	1	–	–	–	–	–	In-situ action recommended
7-49	Upper Sand Coulee B	/				X				X	1	–	–	–	–	–	Use as burial site recommended
7-50	Western	1 /		3	2	X				X		1100	20.63	.5	4688	25,000	
7-51	French Coulee	/ 1		3	2	X		3		X		1	–	–	–	–	
SCM-5	Sand Coulee	/ 1	3		2	X				X		6500	20.63	1.0	4688	139,000	
		/															

MATRIX 4-B
RECLAMATION COMPONENTS BY SITE

SITE DESIGNATION		Seedbed Preparation		Seeding Mixture		Seed Application			Lime Application Rate		Mulch		Liners	
		Harrow	Disk	Dry Site	Moist Site	Broadcast	Drill	Hydroseed	10 ton/acre	20 ton/acre	Hydromulch	Straw, wood fiber, etc.	Clay	Fabric, soil, asphalt, etc.
7-32	Sand Coulee Midtown	X	X		X		X			X		X	X	
7-33	Sand Coulee North	X	X	X			X			X		X		
7-34	Belt SE		X	X				X		X	X			
7-36	Stockett NE	X	X	X				X		X	X			
7-37	Stockett SE	X	X	X			X		X			X		X
7-38	Stockett West Ridge	X	X	X			X			X		X		X
7-39	Subsidence NW Centerville	X	X		X		X			X		X		
7-40	Tracy	X	X		X			X		X	X			
7-41	Tracy NE, A	X	X	X		X				X		X		
7-42	Tracy NE, B	X	X	X		X				X		X		
7-43	Tracy South	X	X	X				X		X	X			X
7-44	Tracy SW	X	X		X	X				X		X		
7-45	Upper Cottonwood A	X	X		X		X			X		X		
7-46	Upper Cottonwood B	X	X		X		X			X		X		
7-47	Upper Cottonwood C	X	X		X	X				X		X		
7-48	Upper Sand Coulee A	X	X		X			X		X	X			
7-49	Upper Sand Coulee B	X	X		X			X		X	X			
7-50	Western	X	X		X	X				X		X		
7-51	French Coulee	X	X		X	X				X		X		

MATRIX 4-A
RECLAMATION COMPONENTS BY SITE

SITE DESIGNATION		Seedbed Preparation		Seeding Mixture		Seed Application			Lime Application Rate		Mulch		Liners	
		Harrow	Disk	Dry Site	Moist Site	Broadcast	Drill	Hydroseed	10 ton/acre	20 ton/acre	Hydromulch	Straw, wood fiber, etc.	Clay	Fabric, soil, asphalt, etc.
7-1	Antelope Creek	X	X	X		X				X		X		X
7-2	Antelope Creek Subsidence	X	X	X		X			X			X		X
7-5	Belt A		X	X				X		X	X			X
7-6	B & M Coulee	X	X	X	X			X		X	X			
7-7	Centerville A	X	X					X		X	X			
7-8	Brown	X	X	X				X		X	X			X
7-9	Centerville B	X	X	X				X		X	X			
7-10	Centerville C	X	X	X	X			X		X	X			X
7-11	Centerville D	X	X					X		X	X			
7-12	Centerville E	X	X	X				X		X	X			X
7-13	Centerville F		X	X	X			X		X	X			
7-14	Centerville G		X		X			X		X	X			
7-16	Centerville Mobile Homes	X	X		X			X		X	X		X	
7-17	Cottonwood Seeps	X	X		X	X			X			X		
7-19	East Belt Mine	X	X		X	X				X		X		
7-20	Giffen	X	X	X			X			X		X		X
7-24	Lewis Coulee		X	X				X		X	X			X
7-26	North Belt Mine	X	X		X			X		X	X		X	
7-27	N. End, NW Slope, Sand Coulee	X	X		X			X		X	X		X	
7-28	Number Five Coulee	X	X		X		X			X		X	X	
7-29	Number Five Coulee Mouth	X	X		X		X			X		X		

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C. Socioeconomic Master Plan

Contents

C. Socioeconomic Master Plan

1. Sand Coulee

a. Effects on local population

1. The perception of social and quality of life issues that could change with mine reclamation efforts

Using the results of the personal survey to identify the perception of local residents on how their quality of life might change with reclamation efforts conducted, a large number of residents indicated they were basically satisfied with their current situation. Thirty-seven percent of the respondents in the survey in this area indicated they had experienced damage to their property from abandoned mine sites and 28 percent indicated that they had definitely experienced some economic loss. From a quality of life point of view, only 13 percent of the residents responding to the survey indicated they felt they were worse off living where they do in this area than other residents of rural Cascade County. Therefore, the conclusion drawn is that, while many of the people in the area believe that certain reclamation efforts would enhance their local quality of life, it couldn't be described as a paramount social issue.

Based on personal interview and survey results, reclamation efforts should be directed at: (1) improving surface water quality without disturbing subsurface water sources; and, (2) improving the aesthetics and vegetation destroyed by the mine seepage, and affected by the presence of waste dumps and adit structures. Changes to the local landscape as a result of reclamation efforts would serve to improve agricultural and residential real estate values, increase the revenues from agricultural crops and livestock, and, perhaps as important

as any benefit, should reduce the risk of personal health or safety problems for the individuals who live and work in the area.

2. The estimate of economic effects of reclamation

Immediate economic impacts to the area resulting from a wide scale reclamation of the polluted areas are divided into three separate categories: First, farm and ranch income improvements; secondly, business improvements in Great Falls and the surrounding communities; and thirdly, from residential property value appreciation.

Based on our previous assessment of the number of acres that are being devalued because of pollution, the following figures are derived: annual farm and ranch income in this region could increase by $3,022 from cropland and $14,790 from rangeland for a total of $17,812 per year from agricultural improvements. Considering a 20 year timeframe to the year 2000, present value of that income would be $174,879, at a discount rate of eight percent.

Using that present value of farm and ranch incomes and the 2.89 multiplier, the present value of business income over 20 years due to reclamation improvements in the area could amount to $505,400. The appreciation in homeowner property values as a result of massive reclamation efforts could be as high as $456,000 the derivation of which is 114 devalued housing units times an appreciated price of $4,000.

The total in terms of present value for reclamation efforts in the area is $1,136,279. This calculation of the economic impact in present dollar terms of an improvement that would last 20 years is a generalized view of positive financial benefits that could accrue to the region with a broad

reclamation improvement plan. The value of specific improvements to single homeowner or landowner's circumstances can be very much more accurately calculated prior to proposed reclamation improvements. Such improvements are underway in several locations in this area, e.g., the Fingers and the Heal mine. The development of a cost benefit analysis for a point specific project will be required before reclamation funds can be obligated.

b. Ownership inventory

1. Ownership descriptions

A complete land ownership identification coverage in the Stockett/Sand Coulee area of Cascade County was performed. The area included the following sections: in Township 19 North, Range 4 East, Sections 1, 12, 13, 14, 23, 24, 25, 35, and 36; in Township 18 North, Range 4 East, Sections 1, 12, 13, and 14; in Township 19 North, Range 5 East, Sections 6, 7, 18, 19, 20, 30, and 31; in Township 18 North, Range 5 East, Sections 6, 7, and 18. Research was conducted in the Cascade County Courthouse in the Assessor's Office, the Treasurer's Office and the Clerk and Recorder's Office to determine the owners name, address, and legal description of the property involved. This information is a part of the appendix to the socioeconomic technical report. Specific detailed maps of these property locations were not reproduced as they are updated continuously and are readily available in the offices of the Assessor in Cascade County.

2. Property owners that would be willing to participate in future reclamation projects

The residential survey of landowners in the Stockett and Sand Coulee areas indicated that 64 percent of the property owners would be willing to participate in mine site reclamation projects if they had input

regarding the project. In some cases, the property owner did not indicate a name and address on the survey form and, therefore, where some property owners suggested that they would be willing to participate, their names were not available.

From the survey questionnaire those who identified themselves as being willing to participate in reclamation projects are listed alphabetically here:

Anna Leah Dolena
Jack Eidel
Robert and Carol Erickson
Adone Giannini
Ronald Guisti
Bernice T. Heal
Albert Korin
Earl A. Lee
E.G. Loeffler
Robert Mandville
Thomas W. Rickard
Mrs. Paula Roof
Gerald Schlosser
Gerold Schwartzenberger
William T. Surmi
Bill Wesland
Donald A. Yureck
Marvine R. Yureck, and Rick Yureck

There definitely are other property owners in the Sand Coulee and Stockett areas who would be interested in participating in mine site reclamation. In many comments on the survey forms the people asked for public meetings and public education of plans and possibilities. At such public presentations a more comprehensive list of interested property owners could be be developed.

2. Belt

a. Effects on local population

1. The perception of social and quality of life issues that could change with mine reclamation efforts

Using the results of the personal survey to identify the perception of local residents and how their quality of life might change with reclamation efforts, a large number of residents are basically satisfied with their current situation. Twenty-four percent of the respondents in the survey in Belt indicated they had suffered pollution to their property from abandoned mine sites and 10 percent indicated they had definitely experienced some economic loss. From a quality of life point of view, only three percent of the residents responding to the survey indicated they felt they were worse off being in Belt or in the Belt area than other residents of rural Cascade County. Therefore, the conclusion drawn is that while many of the people in the area believe that certain reclamation efforts would enhance their local quality of life, it certainly can't be described as a paramount social issue. In fact, it can be best described as a minor problem.

Based on personal interviews and survey results, reclamation efforts should be directed at improving the surface water quality, most particularly Belt Creek, as it winds through the community. The residents appear to want to continue to use the waste piles on roads as necessary and they would like to see plugging of the mine openings and reseeding after clean-up.

Changes to the local landscape as a result of reclamation efforts would serve to improve real estate values in Belt and, over an extended period

of time, would increase the revenues from agricultural lands. The reduction of the risk of personal health or safety is as important as any other benefit.

2. The estimate of economic effects of reclamation

Immediate economic impacts to the Belt area resulting from a broad reclamation effort of the affected areas would be seen in three separate categories: First, agricultural income improvements; secondly, business improvements in Belt and Great Falls; and thirdly, from residential property value appreciation.

Based on assessments of the number of acres that are being devalued because of mine pollution (refer to the socioeconomic technical report), the following figures have been derived: Annual farm and ranch income in this area would increase by approximately $812 a year, all from grazing fees. No cropland was considered damaged from mine pollution. Considering this rangeland income and a 20 year timeframe, the present value of that income would be $7,972, at a discount rate of eight percent.

Using the same value of agricultural income and the 2.89 multiplier, the present value of business income over the 20 year timeframe due to reclamation improvements in this area could amount to $23,039, a relatively small sum. And lastly, the appreciation in homeowner property values as a result of reclamation efforts could be as high as $604,000. This figure is the result of assuming an appreciation in property values of $4,000 for 151 homeowners.

The total then, in terms of present value for reclamation efforts in the Belt area, is $635,011. This calculation of the economic impact and

present dollar terms of an improvement for twenty years is a generalized view of positive financial benefits that could accrue to the region with a broad reclamation improvement plan. The value of specific improvements to single homeowner or landowners circumstance can be much more accurately calculated prior to proposing reclamation improvements. Improvements are underway in several locations in the Belt area, e.g.; Armington Coulee and the Pilgram Mines.

The Soil Conservation Service has its Rural Abandoned Mine Program which addresses point specific pollution and its mitigation or reclamation. They have a project underway currently in the Belt area on the James Milos ranch. A development of cost-benefit analysis for a point specific project is recommended and is, in most cases, required before reclamation funds can be obligated.

b. Ownership inventory

1. Ownership descriptions

A land ownership identification survey in the Belt area of Cascade County was performed. The area includes the following sections: in Township 19 North, Range 6 East, Sections 23, 25, 26, and 36. Research was conducted in the Cascade County Courthouse, in the office of the Assessor, the Treasurer, and the Clerk and Recorder to determine the owner's name, address and the legal description of the property involved. This information is a part of the appendix to the socioeconomic technical report. Specific detailed maps of the property locations were not reproduced as they are updated continuously and are readily available in the office of the Assessor in the Cascade County Courthouse.

2. Property owners that could be willing to participate in future reclamation projects

The residential survey of landowners in the Belt area indicated that 65 percent of the property owners would be willing to participate in mine site reclamation projects if they had an input regarding the project. In some cases the property owner did not indicate a name and address on the survey form and, therefore, where some property owners suggested that they would be willing to participate, their names are unavailable.

From the survey questionnaires those who identified themselves as being willing to participate in reclamation projects are here listed alphabetically:

June Berg
Edith M. Blain
John P. Brutosky
Kenneth Burley
Karol Carlson
John C. Castner
Gary and Judy Crowder
Edward J. Elam, Sr.
Michael Gamble
Roy E. Goodman
Gary E. Gray
Bill Hendrickson
Leo M. Hertz
D. Higen
Dan Hubley
Phillip Kleffner
Russell Leland
Kenneth Maki
James Milos
W.L. Murphy

William Neill
Danell O'Connell
Dennis J. O'Leary
Patrick E. Pierson
Charles F. Remington
Mel W. Rennick
James C. Rubino
Mac L. Savage
Michael Sechena
W.C. Sederholm
Edward Spragg
June Stewart
Lenore Stokes
Maxine Tender
Thomas A. Thompson
Leroy Thayer
Edna Urich
Russel and Joanne Voytoski
James Warehime
June D. Werner
Martin E. Werner
Jim Whitaker
Burt Williamson
P.M. Wraught
Russell E. Zanto
Michael R. Zuhoski

There definitely are other property owners in the Belt area who would be interested in participating in the mine site reclamation. In many comments on the surveys and in conversations with the people in the area, they would like public meetings and public education of plans and possibilities toward reclamation efforts. At such public presentations, a more comprehensive list of interested property owners could be developed.

VII. Regulatory framework

Title IV of the federal statute "Surface Mining Control and Reclamation Act of 1977" (Pub. L.95-87) authorized creation of an abandoned mine reclamation fund. Funding for this program is derived largely from a fee levied on every ton of coal mined. The development of Montana's Permanent Program enabled transfer of this fund's monies in accordance with the Office of Management and Budget Circular No. A-102.

Reclamation objectives and priorities for abandoned mine land projects declare public health, safety and general welfare primary goals. Restoration of land and water, research and demonstration projects, protection of public facilities and development of publicly owned lands are additional objectives for projects funded with these monies.

Specific benefits of reclamation are detailed in ARM 26.4.1235(3). These include:

- (a) protection of human life, health, or safety;
- (b) protection of the environment;
- (c) protection of public or private property;
- (d) abatement of adverse social or economic impacts;
- (e) improved environmental conditions which enhance life;
- (f) improved use of natural resources, including;
    - (i) productive capability;
    - (ii) use of surrounding lands;
    - (iii) enhancement of public facilities;
    - (iv) residential, commercial or industrial developments;
- (g) demonstrate methods and technologies to be used to reclaim areas disturbed by mining.

is attributable to the abandoned mines in the area. If a correlation can be determined, further efforts will be needed to 1) develop alternative solutions to rectify the problems; 2) negotiate with residents and property owners concerning site-specific proposals and 3) complete approved construction of any water control projects.

If vegetative evapotranspiration is to be shown as a feasible acid mine discharge abatement technique, an on-the-ground model should be developed to substantiate its application in the Belt-Sand Coulee area. The success of utilizing vegetation control to reduce deep infiltration and lower groundwater tables in saline seep situations suggests that it could be effective in abating acid discharge.

Research efforts should be directed toward substantiating the correlation between present fallow cropping systems and deep infiltration. Application of this technique for abatement purposes could be evaluated in the course of a multidisciplinary study.

Another major element of the regulatory framework is rules promulgated by the Montana Department of Health and Environmental Sciences regulating water quality. Regulations pursuant to the Montana Water Quality Act include Surface Water Quality Standards and the Montana Pollutant Discharge Elimination System (MPDES). The Surface Water Quality Standards define water quality criteria, prohibiting degradation of surface water and discharge to streams.

The mines in the Sand Coulee and Belt drainages were operational before Montana's stringent laws and regulations were adopted. Although the quality of water presently flowing from adits is far from meeting Montana standards, the Montana Department of Health and Environmental Sciences has not made present surface owners liable for the past actions of mining companies. Surface and mineral ownership have also changed during the intervening years. The result of the current regulatory system in Montana is that no one is regarded legally or financially responsible for past coal mining practices which have created the present water quality problems.

VIII. Recommendations for future research

Water damage to homes from high groundwater levels adjacent to Sand Coulee Creek was discussed at a public meeting held in the community in December, 1981. Subsequent interviews disclosed that several residents had experienced water in their basements from groundwater seepage; overland flow from adjacent Sand-Coulee Creek was cited as a cause in one instance. Water seepage in one home is so constant that a pump must be kept running continuously (Bill Surmi, pers. comm.).

Additional investigation of this situation could determine whether the cause